

**INFORMATIONAL
FEBRUARY 28, 2024**

TAB	DESCRIPTION	ACTION
1	IRSA – HIGHER EDUCATION RESEARCH COUNCIL ANNUAL REPORT	Information Item
2	IRSA – SEMI-ANNUAL REPORT OF APPROVED PROGRAM REQUESTS	Information Item
3	PPGA – IBSDB ANNUAL REPORT	Information Item
4	PPGA – STEM ANNUAL UPDATE	Information Item

**INFORMATIONAL
FEBRUARY 28, 2024**

SUBJECT

Higher Education Research Council Annual Report for Fiscal Year 2023

REFERENCE

February 2017	The Board was provided the annual update of the Higher Education Research Council for FY16 and approved the second reading of amendments to Board Policy III.W.
February 2018	The Board was provided the annual update of the Higher Education Research Council for FY17
June 2019	The Board was provided the annual update of the Higher Education Research Council for FY18
June 2020	The Board was provided the annual report of the Higher Education Research Council for FY19
June 2021	The Board was provided the annual report of the Higher Education Research Council for FY20
February 2022	The Board was provided the annual report of the Higher Education Research Council for FY21
February 2023	The Board was provided the annual report of the Higher Education Research Council for FY22

APPLICABLE STATUTE, RULE, OR POLICY

Idaho State Board of Education Governing Policies and Procedures, Section III.W.
Higher Education Research

BACKGROUND/DISCUSSION

Board Policy III.W. Higher Education Research recognizes the significant role research plays in innovation, economic development, and enhanced quality of educational programs. By developing and leveraging the state's unique research expertise and strengths, Idaho's universities and colleges serve as catalysts to spur the creation of new knowledge, technologies, products, and industries. This in turn leads to new advances and opportunities for economic growth.

The Board's Higher Education Research Council (HERC) provides recommendations to the Board regarding statewide collaborative efforts and initiatives to accomplish these goals and objectives. In addition, HERC provides direction for, and oversees the use of, the limited resources allocated by the Board for higher education research by promoting research activities that will have the greatest beneficial effect on the quality of education and the economy of the state.

HERC also administers the Idaho Global Entrepreneurial Mission (IGEM) Fund programs, disbursement of Infrastructure Funds, and the oversight of matching funds for our Idaho Established Program to Stimulate Competitive Research (EPSCoR) federal grants on the Board's behalf and in compliance with Board Policy III.W. Additional responsibilities include receiving annual reporting on the institutions' activities in relation to the Center for Advanced Energy Studies

(CAES).

HERC-IGEM projects are awarded for competitive state university research in support of the goals of the IGEN initiative. These funds are to be used as seed funding for strengthening Idaho's future by strategically investing in the development of expertise, products, and services which result in state economic growth. While these awards may be for up to three years, the funding is contingent upon successful progress as determined by HERC at an annual review of the project.

CAES is a research and education consortium among the three Idaho public research institutions (Boise State University, Idaho State University, University of Idaho), and the Idaho National Laboratory. The most recent annual CAES report is included in the attachments.

IMPACT

Taking a strategic approach to invest in the state's unique research expertise and strengths will lead to new advances and opportunities for economic growth and enhance Idaho's reputation as a national and international leader in excellence and innovation. This update will provide the Board with the opportunity to provide ongoing input to the Higher Education Research Council on areas of focus and strategic direction.

ATTACHMENTS

- Attachment 1 – FY23 HERC Report Presentation Deck
- Attachment 2 – FY23 HERC Budget Allocation
- Attachment 3 – FY23 Research Performance Measure Reports
- Attachment 4 – FY23 Research Activity Reports
- Attachment 5 – FY23 Infrastructure Summary Reports
- Attachment 6 – FY23 Undergraduate Research Report
- Attachment 7 – FY23 Idaho Conference on Undergraduate Research Report
- Attachment 8 – FY23 Incubation Fund Grant Reports
- Attachment 9 – FY23 IGEN Grant Annual Reports
- Attachment 10 – 2022 CAES Annual Report

BOARD STAFF COMMENTS AND RECOMMENDATIONS

A full presentation of HERC activities was provided to the Instruction, Research and Student Affairs Committee of the Board on February 15, 2024.

BOARD ACTION

This item is for informational purposes only.

Higher Education Research Council (HERC)

Report on activities from July 1, 2022 - June 30,
2023
(Fiscal Year 2023)

Dr. Martin Blair, Chair



Attachments

- FY23 HERC Budget Allocation
- FY23 Performance Measures Reports
- FY23 Research Activity Reports
- FY23 Infrastructure Summary Reports
- FY23 Undergraduate Research Reports
- FY23 Idaho Conference on Undergraduate Research Report
- FY23 Incubation Fund Grant Report
- FY23 IGEM Grant Annual Reports

HERC - Mission

Strengthen the research capabilities at Idaho's public four-year institutions and contribute to the economic development of the state of Idaho.

HERC - Purpose, Vision, and Role

- **Purpose:** To provide vision, leadership, and strategic financial support to the research endeavors at Idaho's higher education institutions.
- **Vision:** Idaho will become a research destination in key discipline areas.
- **Role:** To manage HERC funds, influence the research endeavor in higher education in Idaho, and monitor key factors that might impact the funder and influencer roles HERC plays.

HERC Membership

Higher Education Representatives

Dr. Nancy Glenn, *Boise State University*

Dr. Martin Blair, *Idaho State University (Chair)*

Dr. Christopher Nomura, *University of Idaho*

Dr. Grace Anderson, *Lewis-Clark State College (Chair-Elect)*

Industry Representatives

Marianne Walck, *Idaho National Laboratory*

Eileen Barber, *Keynetics*

Heather Messenger, *Life Sciences and Biotech Industry*

Douglas Sayer, *Premier Technology Inc.*

FY23 HERC Budget Allocation

HERC IGEM Grants	\$2,077,000
Research Infrastructure Funds	\$854,000
Matching Grants (EPSCoR match)	\$800,000
Incubation Fund	\$40,000
Undergraduate Research	\$265,000
<u>Administrative Costs</u>	<u>\$38,800</u>
Total	\$4,074,800

Research Infrastructure

Funding to support science, engineering, and other research infrastructure

FY23 Infrastructure Budget - \$854,000

Major line items:

- **BSU** – HPC (High Performance Computing) Equipment and Software at \$117,000. MOCVD at \$80,000
- **ISU** – Sequencer that comes with a laptop for DNA, ground automated sensor & centrifuge, repair of power supply, and 4 Ghz oscilloscope all combined at \$119,492
Repairs/environmental improvements made to the gas used in chiller systems at \$87,441
- **LCSC** – Salary and fringe for LC State Librarian to support undergraduate and faculty research efforts at \$39,103
- **UI** – Exterior Water Main for the Hagerman Fish Culture Experiment Station at \$55,392
Implementation of a new Research Information Management System platform at \$48,600
Research Computer and Data Services equipment upgrades at \$36,528

Undergraduate Research

Funding to support STEM undergraduates in research projects and travel to conferences

FY23 Undergraduate Research Budget - \$265,000

Student research projects supported in FY23:

- **BSU** – 19 students across 13 different STEM disciplines were supported which helped build meaningful experiential learning experiences for Idaho students and supporting faculty research.
- **ISU** – Grants were made to six labs with projects that included two to three undergraduate students with a total participation of 15 students. Students who participated in HERC funded undergraduate research had the opportunity to present their research at the ISU Undergraduate Research Symposium 2023. 32 students presented posters to the campus community. Several participants received invitations to present their work at the BSU Idaho Conference on Undergraduate Research (ICUR) held in July 2023. 60 individuals from Idaho State University participated in ICUR; 12 students presented research.
- **LCSC** – 18 students supported in their semester long or year long projects.
- **UI** – 12 Summer Undergraduate Research Fellowships (SURF) were granted. Each student was provided with a \$5,000 stipend in the form of a fellowship which allowed them to devote full time effort to their projects. Each student was also provided with \$1,000 to help offset materials and supplies and other project-related expenses.

Idaho Conference on Undergraduate Research (ICUR)

Funding for a two-day undergraduate conference held each July. During FY23 it was held on July 19 and 20, 2023.

FY23 ICUR Budget - \$40,000

FY23 ICUR Highlights/Outcomes:

- HERC funds allowed each of the three research universities to reserve space and technology along with catering to host a local optional reception. In addition, event coordinators were able to purchase a license that allowed them to use a larger Zoom room and better host the event
- 591 people registered for the event
- 335 attendees participated in zoom sessions from over 30 different institutions/organizations
- 196 poster presentations
- 533 project collaborators including 250 undergraduate students, 79 graduate students, and 164 faculty (plus some postdoctoral fellows, high school students, and other community members)
- Two full days of workshops and presentations took place on Boise State University Campus

Incubation Fund

Funding for faculty members at the state's baccalaureate/post-baccalaureate institutions for research that demonstrate potential for economic benefit or cost savings for the State.

- 1-year grants
- FY23 IF Grant Budget: \$40,000
- Active Grant in FY23: 1

FY23 Active Incubation Fund Grant

Idaho I-Corps Ignite - \$40,000

- Idaho I-Corps Ignite is a four- to six-week summer program devoted to helping Idaho university faculty, post-doctoral, and graduate students advance their ideas. The program is a partnership that includes Boise State University, Idaho State University, University of Idaho, and the Center for Advanced Energy Studies (CAES).
- The program delivers training, provides a network, facilitates connections to service and capital providers, and establishes a scalable structure for faculty seeking to go to market with their ideas.
- The program was funded by in-kind contributions of faculty and staff time from each institution, and \$2,500 stipends were provided for each participant.
- The stipend was made possible by the \$40,000 IGEM HERC grant. The six-week program began in June 2022 and met twice weekly for 90 minutes.
- 13 applications were submitted. A cohort of seven teams was formed (due to not all 13 applicants choosing to participate).
- All seven participants completed the entire program, and during the last cohort meeting, each pitched their project to a virtual audience of university and community leaders.
- Of these seven teams, two completed their first milestone, receiving an additional \$2,500 stipend. One went on to complete a second milestone for an additional \$2,500.
- Remaining funds were used for additional training which focused on research-based technology venture products and services, allowing teams to realize the commercial potential of their research and innovation.

Idaho Global Entrepreneurial Mission Fund (IGEM)

Competitive grant program used as seed funding for strengthening Idaho's future by strategically investing in the development of expertise, products, and services which result in state economic growth.

- 1- to 3-year grants up to \$700,000 per year
- FY23 IGEM Grant Budget – \$2,077,000
- Active Grants in FY23: 3

FY23 Active IGEM Grants

IGEM 22-001: The Cyberdome: An Investment in Idaho's Cybersecurity Future

Boise State University - \$700,000 – Year 2

IGEM 22-002: Boise State University Food and Dairy Innovation Center (FDIC)

Boise State University - \$684,000 – Year 2

IGEM 23-001: Library of Reconfigurable Immersive Attack and Defend Scenarios for Cybersecurity Research and Workforce Development (RADICL)

University of Idaho – \$693,000 – Year 1

IGEM 22-001: The Cyberdome: An Investment in Idaho's Cybersecurity Future

- The Cyberdome is a Security as a Service (SECaaS) oriented platform meant to leverage force-multiplying efforts of students to secure critical cyber/physical assets of rural and remote clients.
- The project has funded an equivalent of 32 full student internships.
- Student workers from five public institutions (BSU, CWI, CEI, LCSC, and UI) worked together to monitor & detect client issues.
- Five papers were submitted, with one being selected for publication.
- There are nine active clients and nine prospective clients in varying stages of movement forward towards activation, far exceeding the original grant goal of five clients.
- Funding requests are being put forward in support of Governor Little's Cybersecurity Task Force objectives. The Cyberdome specific request included state appropriations equal to four full-time support mentors, paid internships for up to 55 students across the state, and platform support for up to 18 rural communities.
- PI Vasko is actively and creatively pursuing sustainable funding from employer partners and at the same time executing on an outreach campaign to market across the nation.

IGEM 22-002: Boise State University Food and Dairy Innovation Center (FDIC)

- The vision of this project is to create a Food and Dairy Innovation Center (FDIC) at Boise State University. The FDIC will utilize science and technology to move beyond the current standards in the food and dairy sectors. The center will serve as a research core facility for regional academic institutions and industry.
- Completed the design and planning of FDIC labs, obtained bids, and contracted with state approved contractors for laboratory construction of FDIC lab modules 1 and 2 to be completed in 2024.
- In year 2, this project aimed to submit 10 grants and generate \$1M in external funding. The team was able submit 22 proposals with 14 of them getting funded and three pending, for a total of \$3,130,366.
- In addition, the FDIC received BUILD Dairy funds in the amount of \$421,848.
- Mentored 12 graduate students, 45 undergraduate students, and six full-time staff.
- Published four papers with more submissions in progress.
- Extensive engagement with private industry partners on external grants and sponsors of funded projects leading to the hiring and continued employment of three postdoctoral researcher and two research technicians for the FDIC.
- In the final year of this project PI McDougal will explore the initiation of a start-up company to facilitate the development of intellectual property for the promotion of economic development in Idaho.

IGEM 23-001: Library of Reconfigurable Immersive Attack and Defend Scenarios for Cybersecurity Research and Workforce Development (RADICL)

- Successfully built a new Reconfigurable Attack-Defend Instructional Computing Laboratory (RADICL) at the University Place campus in Idaho Falls which offers researchers, students, and trainees a controlled live-fire environment like no other currently available.
- Created a private cloud environment to support the reconfigurable virtual spaces for cybersecurity and energy research and training in order to support the needed “cyberspace” environment.
- Expanded relationships with private sector and industry partners, including Schweitzer, Engineering Laboratories, Westinghouse (now WESCO), Datacast Technologies, and Edge Velocity to begin integrating their technologies into the laboratory.
- Produced four journal publications and five conference papers. Also delivered a report to the U.S. House of Representatives regarding the cybersecurity of the electric distribution system (to be made public in coming months).
- Submitted five additional grant funding proposals (currently over \$8 million under review). Been successful in securing an additional \$100,000 per year from their partnership with Idaho National Laboratory (INL).
- Post-doctoral fellowship positions created to be filled in future reporting period.
- One Master’s student directly funded in initial reporting period. One PhD student directly funded in next reporting period (Spring 2023). 12 additional undergraduate and graduate students directly involved in supporting initial project efforts.
- Going forward, the project focus will shift from equipment and materials acquisition to student education and research involvement by directly supporting multiple graduate students and post-doctoral fellows each year.

Thank you.



FY 2023 Allocation of HERC Funds

	Allocation	\$4,074,800
	HERC IGEN	\$2,077,000
	Infrastructure Funds	\$854,000
	Matching Grants (EPSCoR Match)	\$800,000
	Incubation Fund	\$40,000
	Undergraduate Research	\$265,000
	Administrative Costs	\$38,800
TOTAL BALANCE	Sum	\$4,074,800
IGEM Funds		
BSU	IGEM 22-001	\$700,000
BSU	IGEM 22-002	\$684,000
UI	IGEM 23-001	\$693,000
Total IGEN	Committed IGEN Funds	\$2,077,000
Research Infrastructure Funds		
BSU		\$250,000
ISU		\$250,000
UI		\$250,000
LCSC		\$104,000
Total Infrastructure		\$854,000
Matching Award Grants		
NSF-EPSCoR		\$800,000
Total Matching Grants		\$800,000

Targeted Research

Idaho iCORPS Ignite \$40,000

Total Targeted Research \$40,000

Undergraduate Research

BSU \$65,000

ISU \$65,000

UI \$65,000

LCSC \$30,000

Idaho Conference for Undergraduate Research (ICUR) \$40,000

Total Undergraduate Research \$265,000

Administrative Costs

FY23 Administrative Costs \$38,800

Total Administrative Costs \$38,800

Total Budget / Allocation \$4,074,800

Boise State University

Performance Measure	FY2019	FY2020	FY2021	FY2022	FY2023	Benchmark
Statewide amount of total annual research and development expenditures as reported in the National Science Foundation (NSF) Higher Education Research and Development Survey, 5 Year Average.	\$35,924,932	\$38,318,235	\$41,113,857	\$43,638,927	Not Available	5% average increase across the previous 5 years
Statewide amount of total annual research and development expenditures as reported in the National Science Foundation (NSF) Higher Education Research and Development Survey. % increase over prior 5 yr period.	8.0%	6.7%	7.3%	6.1%	Not Available	5% average increase across the previous 5 years
Number of new sponsored project proposals submitted by an Idaho University that are collaborative, and have a subaward (or are NSF Collaborative) with another Idaho institution of higher education (in either direction).	34	35	23	26	30	5% annual increase
Number of new sponsored project awards to an Idaho University that are collaborative, and have a subaward (or are NSF Collaborative) with another Idaho public postsecondary institution (in either direction).	19	25	12	9	13	3% annual increase
Number of competitive research project per year supported by the Idaho Higher Education Research Council that directly address research opportunities outlined in Higher Education Research Strategic Plan and that involves at least two Idaho public postsecondary institutions.	1	2	2	1	0	1 per year
Statewide amount of awards with the Idaho National Laboratory by the institutions. 5 year average.	\$2,510,275	\$2,629,765	\$2,760,431	\$2,858,774	\$2,654,282	5% average increase across the previous 5 years
Statewide amount of awards with the Idaho National Laboratory by the institutions. % increase over prior 5 yr period.	18.3%	4.8%	5.0%	3.6%	-7.2%	5% average increase across the previous 5 years
Number of new sponsored projects with private sector contributions (funds, in-kind, etc.). 5 year average. This funding from private sector only.	13.2	13.8	10.4	9.2	9.8	5% average increase across the previous 5 years
Number of new sponsored projects with private sector contributions (funds, in-kind, etc.). % increase over prior 5 yr period. This funding from private sector only.	-2.9%	4.5%	-24.6%	-11.5%	6.5%	5% average increase across the previous 5 years

Boise State University

Number of new sponsored projects with private sector contributions (funds, in-kind, etc.). 5 year average. This funding federal pass-through only.	4.2	3.8	4.2	4.6	4.4	5% average increase across the previous 5 years
Number of new sponsored projects with private sector contributions (funds, in-kind, etc.). % increase over prior 5 yr period. This funding federal pass-through only.	16.7%	-9.5%	10.5%	9.5%	-4.3%	5% average increase across the previous 5 years
Number of technology transfer agreements, as defined the Association of University Technology Managers, resulting from research at the institutions. 5 year average.	28.8	25.6	24.2	26.0	32.6	5% average increase across the combined institutions from the previous 5 years
Number of technology transfer agreements, as defined the Association of University Technology Managers, resulting from research at the institutions. % increase over prior 5 year period.	-1.4%	-11.1%	-5.5%	7.4%	25.4%	5% average increase across the combined institutions from the previous 5 years
Number of invention disclosures resulting from research at the institutions. 5 year average.	15.8	17.0	17.0	16.8	16.0	5% average increase across the previous 5 years
Number of invention disclosures resulting from research at the institutions. % increase over prior 5 year period	5.33%	7.59%	0.00%	-1.18%	-4.76%	5% average increase across the previous 5 years
Number of invention disclosures vetted through entrepreneurial competitions or industry partnerships resulting from research at the institutions.					6	2 per year per institution
Number of undergraduate and graduate students at the institutions paid from sponsored projects. 5 year average	966.6	1042.4	1118.0	1215.6	1247.2	3% average increase across the previous 5 years
Number of undergraduate and graduate students at the institutions paid from sponsored projects. % increase over prior 5 year period	11.57%	7.84%	7.25%	8.73%	2.60%	3% average increase across the previous 5 years
Percentage of degree-seeking undergraduate students at the institutions who had a research experience. 5 year average	36.4%	39.2%	39.0%	38.8%	38.1%	10% average increase across the previous 5 years
Percentage of degree-seeking undergraduate students at the institutions who had a research experience. % increase over prior 5 year period	8.41%	7.54%	-0.49%	-0.57%	-1.71%	10% average increase across the previous 5 years
Number of faculty and staff at the institutions paid from sponsored projects. 5 year average	854.6	930.0	993.2	1066.6	1121.2	3% average increase across the previous 5 years
Number of faculty and staff at the institutions paid from sponsored projects. % increase over prior 5 year period	8.4%	8.8%	6.8%	7.4%	5.1%	3% average increase across the previous 5 years

Idaho State University

Performance Measure	FY2023	FY2024	FY2025	FY2026	FY2027	Benchmark
Statewide amount of total annual research and development expenditures as reported in the National Science Foundation (NSF) Higher Education Research and Development Survey,	\$15,501,716	\$0	\$0	\$0	\$0	5% average increase across the previous 5 years
Number of new sponsored project proposals submitted by an Idaho University that are collaborative, and have a subaward (or are NSF Collaborative) with another Idaho public postsecondary institution (in either direction).	37	0	0	0	0	5% annual increase
Number of new sponsored project awards to an Idaho University that are collaborative, and have a subaward (or are NSF Collaborative) with another Idaho public postsecondary institution (in either direction).	31	0	0	0	0	3% annual increase
Number of competitive research project per year supported by the Idaho Higher Education Research Council that directly address research opportunities outlined in this strategic plan and that involve at least two Idaho public postsecondary institutions.	0	0	0	0	0	1 per year
Statewide amount of awards with the Idaho National Laboratory by the institutions as reported in the National Science Foundation (NSF) Higher Education Research and Development Survey.	\$2,499,045	\$0	\$0	\$0	\$0	5% average increase across the previous 5 years
Number of new sponsored projects with private sector contributions (funds, in-kind, etc.).	24	0	0	0	0	5% average increase across the previous 5 years
Number of technology transfer agreements, as defined the Association of University Technology Managers, resulting from research at the institutions.	1	0	0	0	0	5% average increase across the combined institutions from the previous 5 years
Number of invention disclosures resulting from research at the institutions.	1	0	0	0	0	5% average increase across the previous 5 years
Number of invention disclosures vetted through entrepreneurial competitions or industry partnerships resulting from research at the institutions.	1	0	0	0	0	2 per year per institution
Number of undergraduate and graduate students at the institutions paid from sponsored projects.	376	0	0	0	0	3% average increase across the previous 5 years
Percentage of degree-seeking undergraduate students at the institutions who had a research experience.	36%	0%	0%	0%	0%	10% average increase across the previous 5 years
Number of faculty and staff (combined metric) at the institutions paid from sponsored projects.	231	0	0	0	0	3% average increase across the previous 5 years

Idaho State University

K-20 Statewide Stratgic Plan Performance Measures						
Percentage of students participating in undergraduate research.	36%	0%	0%	0%	0%	Note: This measure is being requested independently from your IR offices.

University of Idaho

Performance Measure	FY2018	FY2019	FY2020	FY2021	FY2022	Benchmark
Statewide amount of total annual research and development expenditures as reported in the National Science Foundation (NSF) Higher Education Research and Development Survey, 5 Year Average.	\$103,334,253	\$106,568,703	\$109,640,230	\$110,327,710	\$111,540,817	5% average increase across the previous 5 years
Statewide amount of total annual research and development expenditures as reported in the National Science Foundation (NSF) Higher Education Research and Development Survey. % increase over prior 5 yr period.	3.13%	3.13%	2.88%	0.63%	1.10%	5% average increase across the previous 5 years
Number of new sponsored project proposals submitted by an Idaho University that are collaborative, and have a subaward (or are NSF Collaborative) with another Idaho institution of higher education (in either direction).	23	17	16	18	17	5% annual increase
Number of new sponsored project awards to an Idaho University that are collaborative, and have a subaward (or are NSF Collaborative) with another Idaho public postsecondary institution (in either direction).	14	9	11	6	6	3% annual increase
Number of competitive research project per year supported by the Idaho Higher Education Research Council that directly address research opportunities outlined in Higher Education Research Strategic Plan and that involves at least two Idaho public postsecondary institutions.	N/A, new metric	N/A, new metric	N/A, new metric	N/A, new metric	2	1 per year
Statewide amount of awards with the Idaho National Laboratory by the institutions. 5 year average.	20.60	22.80	25.40	28.60	31.20	5% average increase across the previous 5 years
Statewide amount of awards with the Idaho National Laboratory by the institutions. % increase over prior 5 yr period.	-0.96%	10.68%	11.40%	12.60%	9.09%	5% average increase across the previous 5 years
Number of new sponsored projects with private sector contributions (funds, in-kind, etc.). 5 year average. This funding from private sector only. See Note A	47.80	48.80	50.80	52.20	50.60	5% average increase across the previous 5 years
Number of new sponsored projects with private sector contributions (funds, in-kind, etc.). % increase over prior 5 yr period. This funding from private sector only. See Note A	-2.45%	2.09%	4.10%	2.76%	-3.07%	5% average increase across the previous 5 years
Number of new sponsored projects with private sector contributions (funds, in-kind, etc.). 5 year average. This funding is federal pass-through only. See Note A	16.60	18.40	20.40	21.20	21.60	5% average increase across the previous 5 years

University of Idaho

Number of new sponsored projects with private sector contributions (funds, in-kind, etc.). % increase over prior 5 yr period. This funding is federal pass-through only. See Note A	3.75%	10.84%	10.87%	3.92%	1.89%	5% average increase across the previous 5 years
Number of technology transfer agreements, as defined the Association of University Technology Managers, resulting from research at the institutions. 5 year average.	8.2	7.6	6.6	7	8.6	5% average increase across the combined institutions from the previous 5 years
Number of technology transfer agreements, as defined the Association of University Technology Managers, resulting from research at the institutions. % increase over prior 5 year period.	-2.38%	-7.32%	-13.16%	6.06%	22.86%	5% average increase across the combined institutions from the previous 5 years
Number of invention disclosures resulting from research at the institutions. 5 year average.	19	20.6	24.8	27.2	27	5% average increase across the previous 5 years
Number of invention disclosures resulting from research at the institutions. % increase over prior 5 year period	9.20%	8.42%	20.39%	9.68%	-0.74%	5% average increase across the previous 5 years
Number of invention disclosures vetted through entrepreneurial competitions or industry partnerships resulting from research at the institutions.	N/A, new metric	N/A, new metric	N/A, new metric	N/A, new metric	11	2 per year per institution
Number of undergraduate and graduate students at the institutions paid from sponsored projects. 5 year average	1164.8	1194.8	1180	1151.4	1118.6	3% average increase across the previous 5 years
Number of undergraduate and graduate students at the institutions paid from sponsored projects. % increase over prior 5 year period	4.30%	2.58%	-1.24%	-2.42%	-2.85%	3% average increase across the previous 5 years
Percentage of degree-seeking undergraduate students at the institutions who had a research experience. 5 year average	61%	61%	60%	60%	57%	10% average increase across the previous 5 years
Percentage of degree-seeking undergraduate students at the institutions who had a research experience. % increase over prior 5 year period	-0.93%	-0.41%	-0.51%	-1.08%	-3.98%	10% average increase across the previous 5 years
Number of faculty and staff at the institutions paid from sponsored projects. 5 year average	1218.20	1246.20	1264.80	1273.80	1286.20	3% average increase across the previous 5 years
Number of faculty and staff at the institutions paid from sponsored projects. % increase over prior 5 year period	0.91%	2.30%	1.49%	0.71%	0.97%	3% average increase across the previous 5 years

Performance Measure Explanatory Notes:

Note A - Activity with private sector/industry - (a) is funding from private sector, and (b) is funding from private sector, federal flow through.

Boise State University

Sponsored Project Activity Report FY2023

Awards for the Period July 1, 2022 through June 30, 2023

Activity Type		Federal	State	Industry	Other	Total	% of Grand Total
Instruction:							
	Sponsored Programs	\$ 139,420	\$ 1,098,554	\$ -	\$ 327,526	\$ 1,565,500	
	State Instruction Appropriations	\$ -	\$ -	\$ -	\$ -	\$ -	
	Subtotal Instruction	\$ 139,420	\$ 1,098,554	\$ -	\$ 327,526	\$ 1,565,500	1.72%
Research:							
	Sponsored Programs	\$ 45,546,639	\$ 417,885	\$ 655,742	\$ 2,898,301	\$ 49,518,567	
	State Research Appropriations	\$ -	\$ 1,400,000	\$ -	\$ -	\$ 1,400,000	
	Subtotal Research	\$ 45,546,639	\$ 1,817,885	\$ 655,742	\$ 2,898,301	\$ 50,918,567	55.95%
Other Sponsored Activities:							
	Sponsored Programs	\$ 33,855,751	\$ 2,046,029	\$ 323,585	\$ 2,183,830	\$ 38,409,195	
	State Other Sponsored Activities Appropriations	\$ -	\$ 111,500	\$ -	\$ -	\$ 111,500	
	Subtotal Other Sponsored Activities	\$ 33,855,751	\$ 2,157,529	\$ 323,585	\$ 2,183,830	\$ 38,520,695	42.32%
More Than One Type							
	Sponsored Programs	\$ 9,500	\$ -	\$ -	\$ -	\$ 9,500	
	State Other Sponsored Activities Appropriations	\$ -	\$ -	\$ -	\$ -	\$ -	
	Subtotal More Than One Type	\$ 9,500	\$ -	\$ -	\$ -	\$ 9,500	0.01%
Grand Totals		\$ 79,551,310	\$ 5,073,968	\$ 979,327	\$ 5,409,657	\$ 91,014,262	
Percent of Grand Total		87.41%	5.57%	1.08%	5.94%	100%	100%

Expenditures for the Period July 1, 2022 through June 30, 2023

Activity Type		Federal	State	Industry	Other	Totals	% of Grand Total
Instruction:							
	Sponsored Programs	\$ 2,064,059	\$ 1,299,752	\$ -	\$ 412,506	\$ 3,776,317	
	State Instruction Appropriations	\$ -	\$ 176	\$ -	\$ -	\$ 176	
	Subtotal Instruction	\$ 2,064,059	\$ 1,299,927	\$ -	\$ 412,506	\$ 3,776,493	5.76%
Research:							
	Sponsored Programs	\$ 36,370,509	\$ 1,789,322	\$ 345,658	\$ 1,377,254	\$ 39,882,742	
	State Research Appropriations	\$ -	\$ 1,575,438	\$ -	\$ -	\$ 1,575,438	
	Subtotal Research	\$ 36,370,509	\$ 3,364,760	\$ 345,658	\$ 1,377,254	\$ 41,458,180	63.18%
Other Sponsored Activities:							
	Sponsored Programs	\$ 17,383,881	\$ 1,482,953	\$ 226,907	\$ 1,167,105	\$ 20,260,847	
	State Other Sponsored Activities Appropriations	\$ -	\$ 125,538	\$ -	\$ -	\$ 125,538	
	Subtotal Other Sponsored Activities	\$ 17,383,881	\$ 1,608,491	\$ 226,907	\$ 1,167,105	\$ 20,386,385	31.07%
Grand Totals		\$ 55,818,450	\$ 6,273,178	\$ 572,565	\$ 2,956,865	\$ 65,621,058	
Percent of Grand Total		85.06%	9.56%	0.87%	4.51%	100%	100%

Idaho State University
Office for Research
Award Breakdown by Funding Agency Type and Project Type
July 1, 2022 through June 30, 2023

	Federal	State	Industry	Other/Foundation	Totals	Percent of Total
Research	6,902,397	1,398,454	5,600,858	4,075,478	17,977,187	37%
Training and Instruction	6,536,378	1,267,978	252,094	247,613	8,304,063	17%
Other/Public Service	17,390,213	3,148,358	1,061,005	1,065,366	22,664,942	46%
Totals	30,828,988	5,814,790	6,913,957	5,388,457	48,946,192	100%
Percent of Total	63%	12%	14%	11%	100%	

State = Awards from state of Idaho agencies, including other state universities and colleges

Other/Foundation = Awards from other funding agencies, such as foundations, universities from outside of Idaho, local municipalities, non-profits, etc.

File Name: ISU OR Annual Awards FY23

Idaho State University
Office for Research
Expenditure Breakdown by Funding Agency Type and Project Type
July 1, 2022 through June 30, 2023

	Federal	State	Industry	Other/Foundation	Totals	Percent of Total
Research	3,818,694	2,799,297	3,252,819	1,155,290	11,026,100	37%
Training and Instruction	6,906,903	2,090,807	1,439,742	656,729	11,094,181	37%
Other/Public Service	3,883,148	3,338,865	230,474	131,193	7,583,680	26%
Totals	14,608,746	8,228,969	4,923,035	1,943,212	29,703,961	100%
Percent of Total	49%	28%	17%	7%	100%	

File Name: ISU OR Annual Expenditures FY23

INFORMATIONAL FEBRUARY 28, 2024

ATTACHMENT 4

University of Idaho - FY2022 Research Activity Report

Awards for the Period July 1, 2021 through June 30, 2022

	Federal	State of Idaho	Industry	Other	Total	% of Grand Total	% of Sponsor Total
Instruction:							
Sponsored Programs	\$ 387,188.00	\$ 73,750.06	\$ 33,000.00	\$ 26,964.00	\$ 520,902.06		0.46%
	\$ 387,188.00	\$ 73,750.06	\$ 33,000.00	\$ 26,964.00	\$ 520,902.06	0.33%	
Research:							
Sponsored Programs	\$ 63,344,271.58	\$ 2,003,942.20	\$ 1,342,267.00	\$ 4,612,463.50	\$ 71,302,944.28		62.70%
Federal Land Grant Appropriations (FFY22)	2,899,446.00				2,899,446.00		
State Research Appropriations (CALS,FUR,IGS,EPSCoR)		23,249,145.67			23,249,145.67		
Subtotal Research:	\$ 66,243,717.58	\$ 25,253,087.87	\$ 1,342,267.00	\$ 4,612,463.50	\$ 97,451,535.95	62.88%	
Public Service:							
Sponsored Programs	\$ 38,205,494.01	\$ 1,572,171.81	\$ 410,691.00	\$ 1,712,388.73	\$ 41,900,745.55		36.84%
Federal Land Grant Appropriations (FFY22)	3,091,570.56				3,091,570.56		
State Extension Appropriations		12,021,954.33			12,021,954.33		
Subtotal Public Service:	\$ 41,297,064.57	\$ 13,594,126.14	\$ 410,691.00	\$ 1,712,388.73	\$ 57,014,270.44	36.79%	
Construction:							
Sponsored Programs	-	-	-	-	-	0%	0%
Total Sponsored Programs Funding	\$ 101,936,953.59	\$ 3,649,864.07	\$ 1,785,958.00	\$ 6,351,816.23	\$ 113,724,591.89		
Percent of Total Sponsored Programs	90%	3%	2%	5%	100%		100%
Grand Total of All Funding Per Category	\$ 107,927,970.15	\$ 38,920,964.07	\$ 1,785,958.00	\$ 6,351,816.23	\$ 154,986,708.45		
Percent of All Funding	70%	25%	1%	4%	100%	100%	

Expenditures for the Period July 1, 2020 through June 30, 2021 (includes accruals)

	Federal	State of Idaho	Industry	Other	Institutional	Total	% of Grand Total	% of Sponsor Total
Instruction:								
Sponsored Programs	\$ 2,093,312.32	\$ 142,455.65	\$ 36,490.53	\$ 30,242.89	\$ 314,173.67	\$ 2,616,675.06		2.3%
	\$ 2,093,312.32	\$ 142,455.65	\$ 36,490.53	\$ 30,242.89	\$ 314,173.67	\$ 2,616,675.06	1.5%	
Research:								
Sponsored Programs	\$ 53,054,782.08	\$ 1,209,426.60	\$ 1,922,516.09	\$ 3,744,299.48	\$ 9,104,346.94	\$ 69,035,371.19		61.8%
Federal Land Grant Appropriations	3,105,482.70	-	-	-	-	3,105,482.70		
State Research Appropriations (CALS,FUR,IGS,EPSCoR)		24,325,071.86	-	-	-	24,325,071.86		
State Other Appropriations		7,622,711.49	-	-	-	7,622,711.49		
Other Sources	-	-	-	2,959,034.44	8,555,349.54	11,514,383.98		
Subtotal Research:	\$ 56,160,264.78	\$ 33,157,209.95	\$ 1,922,516.09	\$ 6,703,333.92	\$ 17,659,696.48	\$ 115,603,021.22	66.6%	
Public Service:								
Sponsored Programs	\$ 32,739,664.66	\$ 1,431,994.13	\$ 261,907.73	\$ 1,628,957.01	\$ 3,919,007.68	\$ 39,981,531.21		35.8%
Federal Land Grant Appropriations	3,106,476.32					3,106,476.32		
State Extension Appropriations		12,030,623.63				12,030,623.63		
Other Sources					242,776.40	242,776.40		
Subtotal Public Service:	\$ 35,846,140.98	\$ 13,462,617.76	\$ 261,907.73	\$ 1,628,957.01	\$ 4,161,784.08	\$ 55,361,407.56	31.9%	
Construction:								
Sponsored Programs	-	-	-	-	-	-	0.0%	0.0%
Total Sponsored Programs Funding	\$ 87,887,759.06	\$ 2,783,876.38	\$ 2,220,914.35	\$ 5,403,499.38	\$ 13,337,528.29	\$ 111,633,577.46		
Percent of Total Sponsored Programs	79%	2%	2%	5%	12%	100%		100%
Grand Total of All Funding Per Category	\$ 94,099,718.08	\$ 46,762,283.36	\$ 2,220,914.35	\$ 8,362,533.82	\$ 22,135,654.23	\$ 173,581,103.84		
Percent of All Funding	54%	27%	1%	5%	13%	100%	100%	

FY 2023 INFRASTRUCTURE REPORT SUMMARY – Boise State University

<i>Detailed Allocations</i>	
<i>Library Support</i>	
<i>Graduate Research Assistantships/Research Associates</i>	
<i>Post Doctoral Fellows</i>	
<i>Technician Support</i>	
<i>Maintenance Contracts</i>	
<i>Research Equipment</i>	\$200,000
<i>Competitively Awarded Summer Research Support</i>	
<i>Start-Up Funds for New Hires</i>	\$50,000
<i>Incentives to Reward Faculty for Research Achievements</i>	
<i>Other</i>	
<i>Total Allocation</i>	250,000

FY 2023 INFRASTRUCTURE REPORT SUMMARY – Boise State University

--	--

<i>Detailed Allocations</i>	
<i>Publications in refereed journals</i>	
<i>Presentations at professional meetings and conferences</i>	
<i>Grants Received as a result</i>	
<i>Grants Pending</i>	
<i>Student Participation</i>	
<i>Faculty Participation</i>	
<i>Other Participation</i>	
<i>Patents Awarded</i>	
<i>Patents Pending</i>	
<i>Manuscripts Submitted</i>	

FY 2023 INFRASTRUCTURE REPORT SUMMARY – Boise State University

Notes:

Research Equipment:

HPC (High Performance Computing) Equipment and Software - \$117,000

MOCVD - \$80,000

Cage Wash Pumps – Biomedical Research Vivarium - \$3,000

TOTAL: \$200,000

Startup

COAS Biology startup – Simlar-Williamson - \$25,000

COHS Kinesiology startup – Bacelar - \$25,000

TOTAL: \$50,000

FY 2023 INFRASTRUCTURE REPORT SUMMARY - Idaho State University

	Total \$	Detailed Allocations
<i>Library Support</i>	\$0	
<i>Graduate Research Assistantships / Research Associates</i>	\$0	
<i>Post-Doctoral Fellows</i>	\$0	
<i>Technician Support</i>	\$0	
<i>Maintenance Contracts</i>	\$87,441	Allocated to repair or environmental improvements to the gas used in the chiller systems for the IAC LINACs. Without the chiller system, no contracts or grants could be executed on the LINACs.
<i>Research Equipment</i>	\$119,492	Allocated for repair of power supply and 4 Ghz oscilloscope that is required by research. Sequencer that comes with a laptop for DNA. Ground automated sensor and centrifuge
<i>Competitively Awarded Summer Research Support</i>	\$0	
<i>Start-Up Funds for New Hires</i>	\$0	
<i>Incentives to Reward Faculty for Research Achievements</i>	\$0	

FY 2023 INFRASTRUCTURE REPORT SUMMARY - Idaho State University

Other	\$43,067	Replace the water heat exchanger for the cage washer in Animal Facilities. Re-pipe the boiler to make it stand alone to work for emergency heating to the animal rooms.
Total Allocation	\$250,000	

FY 2023 INFRASTRUCTURE REPORT SUMMARY - Idaho State University

<i>Publications in Refereed Journals</i>	Manuscript in preaparation for submission within the next 3-6 months on detecting water quality patterns and sources of nitrate in the Lower Portneuf Valley
<i>Presenations at Professional Meetings and Conferences</i>	1 presentation at American Geophysical Union
<i>Grants Received as a Result</i>	Battelle Energy Alliance (196K in 2023), Kirkland Airfor Base (67K), Sandia National Lab (52K), Wyle Labs (52K)
<i>Grants Pending</i>	
<i>Student Participation</i>	Participation of 3 graduate students in coordinating calibration, deployment and debugging of sensor issues. 1 graduate student participation in Geosciences.
<i>Faculty Participation</i>	
<i>Other Participation</i>	Sarah Godsey is working with faculty Kathleen Lohse and former faculty member Rebecca Hale on nitrate patterns engagement with post-baccalaureate scholar Carly Bauer, who worked with Sarah Godsey and private landowners to secure permissions for deployment and maintenance, and with the City of Pocatello to update water quality records; also engaged with the Portneuf Watershed Partnership to gather stakeholder advice on where to deploy the sensors.
<i>Patents Awarded</i>	
<i>Patents Pending</i>	

FY 2023 INFRASTRUCTURE REPORT SUMMARY - Lewis-Clark State College

	Total \$	Detailed Allocations	
<i>Library Support</i>	\$44,052	See Library Support Detail tab. (below)	
<i>Qualtrics License</i>	\$7,883	Annual campus license for survey software for use by students as well as faculty and staff for their survey research.	
<i>SPSS campus-wide licenses</i>	\$7,501	Statistical Package for Social Sciences (SPSS) for use by faculty in statistical research methods instruction.	
<i>Research Symposium</i>	\$5,462	Annual LC State Student Research Symposium: Reception Costs \$3367.56; Keynote Speaker costs \$717.8; Printing costs \$1,376.49	
<i>Salary for Research Librarian</i>	\$39,103	Salary and fringe for LC State Librarian to support undergraduate and faculty research efforts.	
<i>Total Expenditures</i>	\$104,000		
	Detailed Allocations		
<i>Publications in Refereed Journals</i>			
<i>Presentations at Professional Meetings and Conferences</i>			
<i>Grants Received as a Result</i>			
<i>Grants Pending</i>			
<i>Student Participation</i>	Students utilize the research librarian and the purchased library resources in coursework, undergraduate research activities, and in preparing for the annual LC State Research Symposium. For survey research, Qualtrics survey software was purchased using HERC Infrastructure funds for studnets' use at no cost.		
<i>Faculty Participation</i>	Faculty utilize the research librarian, the SPSS and Qualtrics software products, the purchased library resources and assist students in preparing for the annual LC State Research Symposium.		
<i>Other Participation</i>	Community members, faculty and staff emeritus, and alumni are invited to attend the research symposium each year.		
<i>Patents Awarded</i>			
<i>Patents Pending</i>			

FY 2023 INFRASTRUCTURE REPORT SUMMARY - Lewis-Clark State College

Ebsco - Nature, Online Journal (Main pkg)	\$14,489.25
Ebsco - Cell Online Journal (Elsevier pkg)	\$2,461.13
Ebsco - AAAS, Science Journal (Lippincott pkg)	\$3,664.68
	\$20,615.06
Infobase Learning - Master Academic College	\$11,775.68
Infobase Learning - Technical and Trade Education Collection	\$1,685.03
Infobase Learning - Allied Health Collection	\$2,248.20
Infobase Learning - Nursing Video Collection	\$3,594.07
Infobase Learning - Feature Films for Education Collection	\$4,133.55
	\$23,436.53

FY 2023 - University of Idaho INFRASTRUCTURE REPORT SUMMARY

	Total \$	Detailed Allocations
Library Support	\$48,600	Implementation of a new Research Information Management System platform
Graduate Research Assistantships / Research Associates	\$5,637	College of Graduate Studies Research Fellowship
Post-Doctoral Fellows	\$449	(2) Post-Doctoral conference registration support
Technician Support	\$7,166	\$7,166 Electron Microscopy on-campus;
Maintenance Contracts	\$0	
Equipment	\$36,528	\$36,528, Research Computer and Data Services equipment upgrades
Start-Up Funds for New Hires	\$0	
Incentives to Reward Faculty for Research Achievements	\$6,505	Excellence in Research Award
Other	\$145,115	\$55,392 for Exterior Water Main for the Hagerman Fish Culture Experiment Station; \$2,335 for PostDoc/Faculty Mentor Award; \$10,000 publishing support; \$1,877 cost share for developing thermostat prototype for holistic climate control system. \$15,000 travel support for the Idaho Geological Survey director to meet with stakeholders; \$10,000 for IRIC Building improvements (Dry labs and research office space) \$2,322 INBRE Student Research award, \$10,000 for Aquaculture Research Institute Director LEAD21 professional development; \$4,506 funding for faculty to strengthen NSF competitive proposal development; \$5,000 research documentary support; \$2,047 Institutional Research Data Analyst position support; \$26,636 Faculty Research Support - LARF
Total Allocation	\$250,000	

FY 2023 - University of Idaho INFRASTRUCTURE REPORT SUMMARY

	Detailed Allocations	
<i>Publications in Refereed Journals</i>	7	
<i>Presentations at Professional Meetings and Conferences</i>	2	
<i>Grants Received as a Result</i>		
<i>Grants Pending</i>		
<i>Student Participation</i>	9	
<i>Faculty Participation</i>	39	
<i>Other Participation</i>	21	
<i>Patents Awarded</i>		
<i>Patents Pending</i>		

NOTE: Other participation includes postdocs, research scientists, research specialists, and stakeholders.

**Higher Education Research Council
Undergraduate Research Fellows
Boise State University
Final Report**

Academic Year 2022-2023

Donna Llewellyn, Executive Director, Institute for Inclusive & Transformative Scholarship
Nico Diaz, Senior Student Initiatives Coordinator, Institute for Inclusive & Transformative Scholarship
Lavanya Seetamraju, Undergraduate Research Project Manager, Institute for Inclusive & Transformative
Scholarship

Introduction

The Institute for Inclusive & Transformative Scholarship oversaw the HERC Undergraduate Research Fellowship at Boise State University Fall 2022, and Spring 2023. HERC funds were used to support Boise State undergraduate students who had minimal research experience with a 10-week mentored research opportunity during the fall and spring semesters. Funds provided by the Higher Education Research Council supported a total of 19 students across 13 different STEM disciplines.

On behalf of the Institute for Inclusive & Transformative Scholarship, we thank the Higher Education Research Council for their generous support in helping build meaningful experiential learning experiences for Idaho students and supporting faculty research.

The Higher Education Research Council provided \$65,000 in funding to support STEM undergraduate research at Boise State University this year. Please see the table below of how stipends and travel awards were dispersed.

HERC Funding:

Stipends	Amount	Details
Fall Semester Research Stipends	\$27,000	9 students at \$3,000 each
Spring Semester Research Stipends	\$33,000	11 students at \$3,000 each
Additional Research Support Spring	\$1,800	1 student at \$1,800
Travel grants	\$3,200	see table below
Total	\$65,000	

Conference	Amount	Details
Intermountain Social Research Lab	\$1088.89	Students travel and lodging to Seattle, WA
APS Conference for Undergraduate Women in Physics (CUWiP)	\$525	2 students registration, travel, and local transportation in Seattle, WA
European Conference on Innovation and Entrepreneurship	\$1,128.15	1 student airfare to Portugal
Raptor Research Foundation Conference	\$457.96	1 student registration and airfare to Albuquerque, NM

The titles and abstracts of the student projects are on the following pages.

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

Fall 2022 Fellows

Alejandra Almaraz, Materials Science and Engineering

Title: Atomic Force Microscopy for Aerospace Applications

Abstract: On July 20, 1969, the Apollo 11 astronauts became the first humans to set foot on the moon. Since then, science has evolved rapidly, and many more astronauts have ventured out to explore more of the vastness of outer space. Although there have been many more successful space missions since then, scientists have discovered that astronauts experience bone and muscle degeneration while in a reduced gravity environment for extended periods of time. The ability to remain in outer space longer with less tissue degeneration would enable more information gathered with less risk. To offer a solution, in collaboration with Dr. Gunes Uzer and Dr. Sean Howard, the nanomechanical properties of mesenchymal stem cell (MSC) nuclei were analyzed using atomic force microscopy (AFM). Specifically, AFM cantilever-based nanoindentation was employed to measure the stiffness (elastic modulus) of treated nuclei relative to control nuclei, indicating the results of the various treatments (low intensity vibrations (LIV), structural knockouts, and pharmaceuticals) applied to the MSCs in Dr. Uzer's lab.

Ellie Cain, Kinesiology

Title: An intervention to combat the negative effects of perfectionism by incorporating elements of self-compassion for youth gymnasts

Abstract: In general, perfectionism means to not accept any results that are not considered "flawless". Perfectionism is a topic that has been widely researched in clinical settings but more research is needed in the sports environment. The current project aims to investigate interventions aimed at reducing perfectionistic tendencies in the sport of gymnastics, a context that may be especially prone to developing perfectionism. There are two widely accepted dimensions of perfectionism: perfectionistic strivings and perfectionistic concerns. Perfectionistic strivings are having high personal standards and wanting to achieve high goals while perfectionistic concerns are worries about making mistakes and evaluating oneself based on performance/mistakes. Perfectionistic striving typically produces adaptive outcomes, while perfectionistic concerns are viewed as the maladaptive aspects of perfectionism including poor performance, anger, anxiety, depression, and other maladaptive behaviors. (Dunn et. al, 2018). It is for this reason that perfectionistic concerns are targeted in interventions. One construct that seems to be possible to contrast the negative effects of perfectionistic concerns is self-compassion. Self-compassion is when someone has an accepting, supportive, and nonjudgmental attitude directed towards themselves and can alleviate suffering while enhancing overall mental health (Mosewich). The goal of incorporating this construct is to highlight perfectionistic striving elements and diminish perfectionistic concerns. For this project, we have developed four workshops that will be introduced to youth gymnasts in order to educate them about perfectionism and combat its negative effects in both sport and other domains. To evaluate the intervention, athletes will complete the Perceived Stress Scale, Sport Multidimensional Perfectionism Scale, and Self Compassion scale before and after the intervention.

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

Zachary Camargo, Chemistry/Mathematics

Title: Synthesis of a Prebiotic Iron Cyanocarbonyl Complex

Abstract: Organometallic compounds delivered by extraterrestrial meteorites may have been crucial to the development of hydrogenase enzymes on early Earth. Here, we used two different published methods to synthesize an iron cyanocarbonyl complex resembling parts of the active sites of these enzymes. This complex was characterized via infrared (IR) spectroscopy and mass spectrometry for use as a standard for future research on the topic of enzyme origins.

Catherine Isaak, Biology

Title: Phenology of the Great Horned Owl (*Bubo virginianus*) population in coastal Texas and its potential effects to the endangered Northern Aplomado Falcon (*Falco femoralis septentrionalis*)

Abstract: Phenology of the Great Horned Owl (*Bubo virginianus*) population in coastal Texas and its potential effects to the endangered Northern Aplomado Falcon (*Falco femoralis septentrionalis*) by Catherine L. Isaak, David Bontrager, and Dr. Jennyffer Cruz

Anthropogenic activities such as wildfire suppression, overgrazing, and climate change contribute to shrub encroachment of native plains and savannas. These changes may seem insignificant but can result in unintended consequences for species inhabiting savannas. The Northern Aplomado falcon was extirpated from the U.S. in the early to middle 1900s, and in 1986 the species was listed as an endangered species under the Endangered Species Act. For three decades, the Peregrine Fund has tried to reintroduce the species in west and south Texas and southern New Mexico. Shrub encroachment has changed the south Texas coastal plains and savannas to the possible disadvantage of the Northern Aplomado Falcon (*Falco femoralis septentrionalis*). We hypothesize that Great Horned Owls (*Bubo virginianus*) (GHOW) have taken advantage of these modified habitats, bringing them in closer proximity to the Aplomado Falcon population in the Laguna Atascosa National Wildlife Refuge. I conducted a literature review to establish phenology patterns for Great Horned Owls across North America. I compared results from the literature review against sound data collected in late December 2021 to early March 2022 with three autonomous recording units and processed the sound data through Raven Pro software. Specific vocal patterns indicative of a GHOW were checked manually. Breeding phenology for GHOWs starts with male advertisement via hooting, followed by an incubation period of 33 days on average and completed by eight weeks with nestlings until fledging. Overall, phenology of GHOWs in coastal Texas resembled those from the Yukon in southwestern Canada, which is surprising given the large latitudinal differences between these two locations. Late December was probably too late to start monitoring GHOWs so we suggest shifting monitoring to starting in November and ending in early March. Appropriate timing of monitoring protocols is essential to ensuring accurate estimates of owl distribution and abundance. GHOWs are likely to prey on juvenile Aplomado Falcons. After fledging, higher numbers of GHOWs juveniles may remain for six to eight months before the juveniles disperse. This represents May to November, possibly to January where there are an increased number of GHOWs in coastal Texas.

Elizabeth Jessmore, Biology

Title: DNA Fecal Extractions; The Power of Poop

Abstract: The research for this HERC fellowship consisted of my involvement in two aligned research projects in the Conservation Genetics Lab at Boise State University, one relating to Sharp-tailed Grouse (*Tympanuchus phasianellus*) the other to Greater Sage-Grouse (*Centrocercus urophasianus*). Both of these grouse are in decline across the western United States, and conservation practitioners are eager to understand

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

the mechanisms that allow for improved conservation success. Fecal pellets of grouse allow for researchers to understand many mechanisms that may be underpinning the local population demographics, including host demographics (from avian DNA), grouse diet (from plant DNA, via trnL DNA metabarcoding), and grouse microbial communities (from microbial DNA, through 16S metabarcoding). The goal of the research is to explore the methodology of extracting DNA from several different communities found within grouse fecal pellets. In particular, Elizabeth will focus on extracting plant DNA from Sharp-tailed Grouse fecal pellets for downstream dietary analyses and host DNA from Greater Sage-grouse fecal pellets to understand host demographics (e.g., host sex). Extracting host DNA from fecal pellets has been challenging, so this work will uncover the best approach for maximizing host DNA yield for downstream analysis. This work will allow researchers to gain multiple insights from the same fecal pellet and use this information to inform conservation management. Questions of interest to conservation practitioners include how are populations related to one another and how grouse transition their diet and microbiomes when translocated to new environments. Because fecal sampling is a non-invasive approach, this allows conservation practitioners an effective and efficient approach to learn more about the birds they manage for improved conservation success.

Payton Lyons, Applied Mathematics/Economics

Title: Using Partial Differential Equations in 3D sagebrush population modeling

Abstract: Partial Differential Equations are of significant use in most fields. From modeling heat diffusion to creating JPEG images. One of the more prevalent uses is in modeling population dynamics. In this project, we created a stage-structured partial differential equation to understand the growth dynamics of sagebrush populations in the great basin. We used real world data to estimate parameter values and then view the modeling results after that to identify ideal initial planting conditions. This project identified that planting sagebrush in a grid created slightly more efficient growth, however in the end it is indiscernible from random planting.

Kerry Molina, Geosciences

Title: Inclusivity in the outdoors as a way to promote diversity in geoscience

Abstract: The lack of inclusion and diversity is identified as “the single largest cultural problem facing the Geosciences today” (Dutt, 2020). In particular, the outdoor field experiences inherent to many geology courses and field camps may keep under-represented groups from participation. Cultural, financial, and experiential barriers influence under-represented student engagement in outdoor recreation. It is possible to break these barriers by giving opportunities that can lead to confidence and support in the pursuit of field-based sciences. My research will implement a program at Boise State called Making Adventures Possible for All Students (MAPAS). MAPAS was developed at UC Santa Barbara in response to the lack of representation and diversity in outdoor recreation. It is a program that creates opportunities for students from different backgrounds to collectively gain experience in nature which can increase engagement in geoscience. MAPAS will promote an inclusive environment, run by students with little-to-no previous experience in the outdoors. I’ve spent the last 7 months working on a NSF-funded student board for assessing inclusivity of the geoscience department, that measures are working and what needs to be improved. I conducted faculty interviews and assisted in a student survey. Lack of outdoor experience is one of the biggest barriers. The geoscience students within the department would benefit from an inclusive program that supports participation and building leadership, especially for under-represented groups that have been historically excluded from outdoor recreation. Some students may face cultural barriers to outdoor

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

experiences, while other people may lack the needed equipment or have physical conditions that limit outdoor engagement. MAPAS will go beyond the geoscience department, it is for everyone. To reach out to students within all the departments takes a lot of time and work. I would use the HERC support to dedicate the time and effort to create this inclusive outdoor program: MAPAS.

The following images showcase the student and their mentor's effort.



Fall 2022 and Spring 2023 HERC Fellows
Research Projects



Allison Muenzer, Materials Science and Engineering

Title: Synthesis of gamma-phase Electrolytic Manganese Dioxide for Use in Aqueous Zinc Batteries

Abstract: Interest in manganese dioxide for use in electrochemical energy storage systems has increased in recent years because it is environmentally friendly, low cost, and enables safer operating conditions. γ -phase electrolytic manganese dioxide (EMD) is of particular interest due to its larger 1x2 tunneling structure that enables greater ion transport and higher specific capacity. MnO_2 can be synthesized from a redox reaction of KMnO_4 and MnCl_2 and the product can be annealed at 200°C for 32 hours for a phase transformation into γ -phase that is verified with XRD. EMD slurry is used to laminate carbon paper heat treated to 350°C for 8 hours to produce the cathode electrode material assembled into coin cells. Rate studies of commercial EMD showed a specific capacity of $\sim 150 \text{ mAhg}^{-1}$ at 0.5C rate, approximately two times greater when compared to synthesized EMD specific capacity of 60 mAhg^{-1} at 0.5C rate. Cycling repeatability improved with the use of synthesized EMD when compared to commercial EMD with less deviation between charge/discharge cycles. EMD has the potential for use in electrochemical energy storage systems once an appropriate dopant used to stabilize the γ -phase can be determined.

Zixi Zhao, Computer Science

Title: A Communicative Fine-grained Privacy Control Framework for Augmented Reality

Abstract: We develop a user interface as part of a privacy control framework for exerting privacy control on Augmented Reality (AR) systems. The AR devices continuously sense the wearer's surrounding environment using cameras and can be a threat source to users' or bystanders' privacy. Our framework projects virtual objects that convey privacy rules intuitively to users and enable revealing those privacy threats as well as improving their privacy-control flexibility. The user first registers privacy needs through standard AR interaction interfaces in the offline stage. Then the user can leverage the AR interfaces using the framework to drive the generation of input control policy through spatial-relation analysis over surrounding physical

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

objects. The policies are loaded in the online stage to enforce input control rules over the visual information of target physical objects and hide sensitive information. We implement our proof-of-concept application under the ARCore platform and test the system functionality and performance on the Samsung S9 Plus device. Our experiment results reveal several challenges and opportunities for the future study of privacy control of AR systems.

Spring 2023 Fellows

Andrew Altman, Engineering

Title: Sagittal Plane Device Analysis for Infant Product Safety

Abstract: Approximately 15,000 infant injuries occurred in inclined sleep products in 2021. This is likely due to infants often being left unattended while sleeping in products not designed for sleep. Prior research has established that a slouched or flexed trunk posture increases the effort required to breathe in adults and infants. This higher demand of breathing due to slumped posture could put infants at a greater risk of suffocation in unsafe products. Currently there is no standardized method of infant body position testing in infant products. To address this, our lab created a 4-segment sagittal plane device. This device aims to provide an accurate and easy way to perform infant product safety testing without the need for testing with real baby participants. My role in this project was determining an analysis method to calculate and validate trunk flexion of the sagittal plane device and compare it to in vivo human subjects data. This was done through assisting with collection and analysis of motion capture data for participants as well as the 4-segment device in 4 different infant products. MATLAB code was created to perform calculations using 3D-vector math, another MATLAB code was used to perform these calculations using a method where the change in distance between the shoulders and ASIS was evaluated to calculate angles for trunk flexion. This data was then analyzed and compared against in vivo participant data. It was found that the changing distance method of analysis produced similar results for the 4-segment sagittal plane device as compared to the participant mean data in the products. This indicates that the changing distance method for calculating torso flexion has less range, producing more consistent values and likely produces values closer to the infant's true flexion when compared to the vector method. The vector method was found to produce variable results compared to the changing distance method.

Rachel Capezza, Biology

Title: Examining Relationships Between Antagonism, Antimicrobial Properties, and Metabolic Profiles of Sagebrush-Associated Microbes

Abstract: The phyllosphere is defined as the aerial parts of a plant which host diverse communities of microbes. This phyllosphere microbiome is an interactive system comprised of interspecific competitive and antagonistic dynamics, often due to the production of antimicrobial metabolites. In addition to influencing overall community structure and host plant health, these metabolites can be isolated and harnessed for biocontrol or medicinal applications. To date, no studies have examined the metabolic properties of microbes isolated from the leaves of sagebrush (*Artemisia tridentata*). In this study, we selected four microbes isolated from sagebrush leaves to determine their interactive properties when co-cultured in vitro and compare these interactions to antimicrobial properties against *E. coli* and *S. aureus*. We hypothesized that the microbes exhibiting antagonism in vitro would express antimicrobial metabolites. The four sagebrush-associated microbes we selected included *Aureobasidium pullulans*, *Bacillus amyloliquefaciens*, *Cladosporium herbarum*, and *Filobasidium wieringae*. We plated three replicates each of monoculture cultures and pairwise co-cultures

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

in each possible combination. Initial analysis revealed antagonistic dynamics between *B. amyloliquefaciens*/*C. herbarum* and *A. pullulans*/*B. amyloliquefaciens* co-cultures. Therefore, we produced crude extracts of these co-cultures and their corresponding monocultures to test against *E. coli* and *S. aureus* in a disk diffusion assay. However, no visible inhibition of bacterial growth occurred under these treatments. Nonetheless, forthcoming work using liquid chromatography-mass spectrometry (LCMS) may serve to isolate the mechanism driving growth inhibition of these isolates *in vitro*. Increasing our understanding of microbial interactions opens the door for myriad real-world applications in agriculture, ecosystem management, and medicine.

Asher Chivvis, Health Studies

Title: Inactivation of *E. coli* 8739 with Cold Atmospheric Pressure Plasma on Strawberries

Abstract: Foodborne illness and food shortages are a detriment to the normalcy of foreign and domestic populations that can cause widespread harms including diseases and a decline of economic productivity. Produce contaminated with *E. coli* causes serious risk to the infant, elderly, and immunocompromised population. Since contamination may be widespread, large amounts of fresh produce needs to be recalled as a result. In an effort to combat these issues, alternative methods of produce sanitation need to be looked at. The use of cold atmospheric-pressure plasma against planktonic bacteria on strawberries has proven that it is capable of inactivating a significant amount of the microorganisms with only a 5 minute exposure time (~99.9% reduction). Cold atmospheric-pressure plasma (CAPP) produces reactive oxygen and nitrogen species that result in oxidative damages to any microorganism that comes into contact with them. Since the cause of decomposition amongst most produce is a result of bacterial/fungal contamination, the removal of microorganisms could have a lasting impact on the shelf life of numerous agricultural products in addition to decreasing the occurrence of illness. Therefore it is prudent to explore the effect of CAPP on fresh fruits and vegetables in order to extend the length of time in which these items are viable for consumers.

Gianella Condor, Materials Science & Engineering

Title: Magneto-mechanical properties of 10M Ni-Mn-Ga after micro-peening

Abstract: Since the discovery of magnetic shape memory alloys, the manufacturing of the Ni-Mn-Ga alloy has been refined to minimize the material twinning stress and to maximize the work output under magnetic actuation. However, applications have lagged behind alloy development partially due to fatigue failure via magnetic and/or mechanical cycling as well the difficulty in controlling twin boundary motion. Previous research has demonstrated that a micropeening surface treatment improves fatigue life while maintaining twin boundary motion. In this study, we present a systematic characterization of the Ni-Mn-Ga material's magnetic and mechanical properties as it was affected by varying intensities of this micropeening surface treatment process. We prepared Ni-Mn-Ga sample via mechanical grinding and polishing and recorded the sample's magnetization and stress/strain characteristics as a baseline. We micropeened the prepared sample in its austenite phase via blasting it with glass beads at a specified pressure and duration. The stress and strain properties of the treated sample was measured via a custom micromechanical tester, and the magnetic properties measured via a vibrating sample magnetometer. The twinning stress of the sample increased and the total strain decreased as the pressure of the micropeen surface treatment increased. Optical micrographs indicate that the surface deformation caused by the micropeening treatment altered the surface roughness and also stabilized a fine twin configuration. Furthermore, we discovered that most of the magnetic-field-induced-stress is suppressed after a 30 psi micropeen treatment.

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

Kaitlyn Linder, Physics

Title: Orientations of Galaxy Clusters in the Universe

Abstract: Galaxy clusters are large, gravitationally bound structures, primarily consisting of stars and dark matter. These two components form different shapes, which are oriented differently. Using data from IllustrisTNG, a publicly available set of hydrodynamical simulations, we calculate the 2D shapes from the inertia tensor of these clusters. Based on shapes measured from various methods, we find the misalignment between each shape. From these misalignments, we find that alignments between shapes measured based on individual particle positions tend to be much stronger than those measured with galaxy positions. We also find that shapes measured with these galaxy positions tend to be much more round as opposed to elliptical in shape.

Jeleana Loa, Radiologic Sciences

Title: Addressing the Nationwide Shortage of Radiologic Technologists

Abstract: There is currently a nationwide shortage of radiologic technologists. A 2022 survey conducted by AMN Healthcare found that radiologic technologists topped the list of new graduate allied health professionals hired by facilities thus indicating that radiologic technologists are in high demand. The purpose of this study is to determine by both division (region) and state, on a per capita basis, how many first-time candidates sat for the American Registry of Radiologic Technologists (ARRT) exam for the years 2020-2022. To accomplish this purpose, I examine the national average of candidates taking the ARRT exam per capita by state and division to determine which states and divisions are performing above or below the national average. The ARRT annually publishes data on the number of prospective radiologic technologists that sat for the registry exam by state. The data published for years 2020-2022 were averaged and then compared to the 2020 United States census data to determine the number of candidates produced in each state and in the nine separate United States census divisions on a per capita basis. The study found that during 2020-2022, divisions one through eight produced one ARRT registry candidate for every 27,033 residents. Division nine (Pacific division) was an outlier producing one ARRT registry candidate for every 50,527 residents. The national average for the time period in question was one ARRT registry candidate for every 29,295 residents, meaning the Pacific division is not producing as many ARRT registry candidates. This information may be used for education and advocacy purposes as well as a basis for further inquiry. Existing radiologic technology programs in states and divisions producing less ARRT candidates per capita could utilize this data to advocate for increased resources. Professional organizations and institutions could advocate to state and federal leaders and policymakers for increased resources for existing and new programs dedicated to producing radiologic technologists in order to keep pace with a shifting and growing population.

Jacob McKeever, Health Studies

Title: Vaping Prevention and Control Interventions Among Adolescents Within the United States: a Review of Present Literature

Abstract: In approximately 18 years since its emergence in the United States, electronic nicotine delivery system (e-cigarettes) usage (also known as vaping) has gained extreme popularity, especially among adolescents and young adults. Negative physiological effects of vaping or e-cigarette use among individuals is well-documented. Vaping has become increasingly widespread, and reached epidemic levels, crucially within the adolescent and young adult demographic aged 13-18 years old. Due to this increase and the negative health outcomes that vaping induces, prevention and control intervention programs have been utilized to

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

curb usage rates among adolescents and young adults. While analysis has been conducted on individual program effectiveness, gaps exist when comparing the effectiveness of programs. In order to fill this gap, a systematic literature review utilizing Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocols was conducted. The goal of the review was to summarize current programs used for vaping prevention and intervention control, determine what prevention and control intervention programs are most effective, and suggest best practices for vaping prevention and intervention control and areas for further research. Two databases (PubMed and Web of Science) were searched in March of 2023. The target population was adolescent and young adult demographic aged 13-18 years old.

Cheyon Sheen, Civil Engineering

Title: A Step toward Resolving Spatiotemporal Distribution of Suspended Sediment Concentration using Remote Sensing

Abstract: It is critical to study Suspended Sediment Concentration (SSC) to improve our understanding of the impacts of wildfires, climate, and anthropogenic on the riverine environments. The processes that contribute to SSC occur over a range of spatiotemporal scales making it difficult to continuously measure and monitor. Traditional methods (e.g., field measurement) require significant resources and often lack the spatial and temporal resolution that is needed for important yet smaller-scale systems like streams. In this study, we create an open-source and low-cost method to estimate SSC using remotely sensed data. Our study aims to elucidate if a machine learning (ML) model is capable of estimating SSC from multispectral imagery using a dataset collected in the laboratory. Another objective is to determine which ML model most accurately estimates SSC. Our methods involve testing and comparing two Machine Learning (ML) models: Random Forest and Linear Regression. Preliminary results indicate that the Random Forest model has the capability of extracting the SSC signal from the imagery and providing superb agreement between experimental and ML-generated data ($R^2=0.99$). Further, our results from the Linear Regression model indicate that the relationship between multispectral imagery and SSC is non-linear and requires a more robust ML model (low correlation of $R^2=-.71$). Continuing work will compare these results with other ML models to develop a cross-validated method for widespread usage in SSC detection. This study contributes to a larger framework, and with a validated model we will be able to quantify the effects of SSC on the entire Snake and Columbia River system. Implications of this research include improving our understanding of SSC and detection methods that augment existing methodologies as tools for stakeholders, government agencies, land managers, and citizen scientists.

Amethyst Tagney, Biology

Title: Pollination biology of a rare and threatened endemic plant: evaluating the flower constancy of Mulford's milkvetch insect visitors

Abstract: The biodiversity of our planet is in peril. Although this crisis impacts all organisms, it is especially concerning regarding plant-pollinator interactions. Flowering plants play a critical role for ecosystem functioning, human and animal nutrition, and offer much-needed habitat for many organisms. However, human impacts such as urbanization, climate change, unsustainable agriculture practices, and the spread of invasive plants, put these plants-and their pollinators-at risk. One such example is *Astragalus mulfordiae*, a rare and threatened plant endemic to southwestern Idaho. To learn more about the decline of *A. mulfordiae* and to develop effective conservation strategies, it is important to understand the pollinator relationships it relies on. This includes identifying which insects visit its flowers, and which are the most important for its pollination. Flower constancy is the tendency of individual pollinators to visit a single kind of flower, and

Fall 2022 and Spring 2023 HERC Fellows
Research Projects

pollinators with high flower constancy can be especially beneficial to plants by increasing the chances they receive pollen from their own species. In this project, we investigate whether insect species that visit *A. mulfordiae* flowers differ in their flower constancy. To evaluate this, we examined pollen collected off insects foraging at *A. mulfordiae* flowers. We first created a pollen reference library using pollen samples from surrounding plant species in *A. mulfordiae* habitat. We then used this library to identify the pollen grains on each insect, with flower constancy measured as the ratio of *A. mulfordiae* pollen to other pollen types. Our findings will provide insight into which insect species are most important for *A. mulfordiae* pollination and will help inform land managers who manage *A. mulfordiae* habitat areas.

Thomas Wenzel, Kinesiology

Title: Surface, but not Age Impact Lower Limb Joint Work During Walk and Stair Ascent

Abstract: During common locomotor activities, such as walk or stair negotiation, older adults exhibit unfavorable lower limb biomechanical changes, including diminished joint torque and power, and proximal mechanical work redistribution that may increase their fall risk. To investigate age-related differences in lower limb work, twelve young (18 to 25 years) and 12 older (> 65 years) adults performed a walk and stair ascent task on a normal, slick, and uneven surface. For each walk and stair ascent trial, synchronous 3D marker trajectories and GRF data were collected. Stance phase positive limb and joint work, and relative joint work were submitted to statistical analysis. Ascending stairs required more positive work than the walk, particularly from the knee, which may increase fall risk. Yet, both walking and ascending stairs over a challenging surface required more, proximally distributed work.

Matthew Wilken, Geosciences

Title: Studying the seasonal fluctuations of dissolved oxygen levels and how various environmental parameters influence them in the context of Dry Creek.

Abstract: The consequences of water scarcity can be devastating, as was experienced by some of my family members who lived through the Cape Town water crisis in 2018. Dramatic changes to lifestyle, including limiting showers to once or twice a week, were required as the community banded together to reduce water usage in order to avoid day zero. My appreciation for water security drove me to take an interest in water science and research that pertains to how water availability and quality can affect the local environment. The Dry Creek tributary plays an important role in a larger ecosystem downstream and is the perfect location to better develop my research interests. I have begun preliminary research in the Fall of 2022, and hope to continue monitoring how changes in temperature and other environmental parameters can affect the dissolved oxygen (DO) levels in Dry Creek. The concentration of dissolved oxygen directly impacts the native and genetically pure Red Band Trout, which, in the future, may come under increased stress as a result of climate change and population growth. This experience will continue to build necessary field and analytical skills that are highly valued in the industry.

TO: Idaho SBOE HERC
FROM: Sonia Martinez, MPA, Undergraduate Research and Outreach Director
DATE: November 16, 2023
Regarding: ISU FY 23 Undergraduate Research SBOE HERC Funds Report

In FY 23, we implemented the FY 22 year plan, emphasizing the student-mentor relationship. Our guiding principle was to ensure the student received effective mentorship that would catalyze the student to develop critical thinking and creative inquiry skills. Because many first-generation college students are unfamiliar with research, we cast a campus-wide net of information to inform students about the paid undergraduate research opportunity, thus creating access for low-income, talented students. According to the Bureau of Labor Statistics, STEM majors are experiencing strong industry growth and the best return on investment. Further, the Council on Undergraduate Research finds that it dramatically improves academic performance, retention, and persistence (CUR, 2023).

We noticed the fruits of the undergraduate research experience cultivated from the student and mentor relationship. The students who participated in this grant cycle significantly improved their confidence, critical thinking skills, and scientific learning that they can apply in a workforce setting. To provide the opportunity to more students, we awarded grants to six labs with projects that included two to three undergraduate students with a total participation of fifteen students. Faculty who received awards were from various research fields in Biological Sciences, Anthropology, and Chemistry. Please take a look at the attached reports from the students and faculty on their successful research outcomes. With gained skill sets in the lab and field work, some participants were able to apply for other funding sources and continue their research in the Summer Research Experience, where they also participated in the Boise State Undergraduate Research Community via Zoom and the Idaho Conference on Undergraduate Research, ICUR. Still, other students report an inspiration to attend graduate school.

A total of \$5,490 in travel funds were awarded to eight students to present their research at numerous national science conferences, including the Society for Integrative and Comparative Biology, the American Chemical Society, and the Society for the Advancement of Hispanic and Native American Students in Science, held in Puerto Rico. Two Anthropology students were guest panelists at the Western Literature Association Conference, where they spoke about their research to a national audience.

Students who participated in funded HERC Undergraduate Research had the opportunity to present their research at the ISU Undergraduate Research Symposium 2023. Thirty-two students presented posters to the campus community. Several participants received invitations to present their work at the BSU Idaho Conference on Undergraduate Research (ICUR) held in July 2023. Sixty individuals from Idaho State University participated in ICUR; twelve students presented research.

The ISU McNair program received \$10,000 in funding for participants to attend conferences to make presentations and conduct research projects.

Five of the six recipients stayed slightly under budget, totaling \$298.75, which was distributed to the lab that went over budget \$481.08.

The attached files include the faculty and student experience reports and the student posters.

Description of Activities

Project Title: Strength and Permeability of High Strength Pervious Concrete

Undergraduate Students: Sam Brandeberry and Brenna Murri

Faculty Advisors: Arya Ebrahimpour and Bruce Savage

Description: The undergraduate students conducted a comprehensive literature review and developed two different mixes of pervious concrete in the Materials Laboratory in the Lillibridge Engineering Laboratory. This was a difficult process and involved multiple mixes. The students tested the materials for both strength and permeability. For the permeability tests, the students had to design and construct their own apparatus; this device worked very well and the students were able to collect good data. In general, everything went well and the students were able to complete all the assigned tasks. In addition, they had two poster presentations, one in CAES Future Net-Zero Innovators Symposium and the other one in ISU Undergraduate Research Symposium. The laboratory report was something new for the students. But we believe they learned a lot on how to write a good technical report. The only thing that we will do differently in the future is to do a better job of keeping track of the budget. Initially we kept good track of the expenses, but unfortunately, we overspent the budget and had to charge the rest of the money to the department account.

Student Report

By

Brenna Murri

I have learned many important skills from this project. The easiest to see is my knowledge of the laboratory equipment and use of the equipment. Before this project, I had not had the opportunity to mix ultra-high performance concrete or use a concrete mixer. With the help of my advisors, lab partner, and other individuals that are a part of the ISU Civil Engineering program I was able to operate and become proficient in the use of multiple lab equipment. I was also able to learn the process often conducted when doing any research. The literary review and research section of this project was very informative in preparing me for the project and in opening my perspective on the uses of pervious concrete.

The research personally benefited me in multiple ways. This has been a good resume builder and provided me the experience to be a good candidate for internships that I am now a part of. This has also benefited me in classes where I have discussed some of the processes that were performed during this project. The knowledge gained allowed me to understand my studies and apply them in a more hands-on way.

This project has helped me to reconsider my future plans. I still want to go into civil engineering and most likely center my studies at ISU around geotechnical engineering; however, I have explored more research opportunities and applied research to my future. This has significantly benefited me and allowed me to grow in ways that would not have been possible without this project.

Student Report

By

Samuel Brandeberry

For this undergraduate research project my colleague Brenna Murri and I conducted a literature review, developed several mixes for high strength pervious concrete in the lab, wrote a final report which can be used for further study, and presented our project at multiple symposiums. I feel like I have learned a lot, and this has been one of if not the most beneficial aspects of my undergraduate study so far. Besides learning technical knowledge, throughout this project I have been introduced to how real research goes. Whether or not we like it things turn up and we don't always get the answers we want. But that is the point of the research. Understanding the processes of making samples, taking adequate notes, and conducting experiments has seemed to be a point of growth and I believe my colleague and I have improved much from the start. This experience has been a great introduction to conducting masters research and has gotten me to think more about continuing my education post my undergraduate degree. I appreciate the opportunity to have attended the Future Net Zero Initiative research symposium and have networked with future leaders in our field, and to have presented to them along with at the ISU undergraduate research symposium. This project has also gotten me more involved and improved my personal relations with the engineering faculty at ISU, who have been a pleasure to work with. I especially would like to thank Dr. Bruce Savage and Dr. Arya Ebrahimpour for their mentorship as well as Brenna Murri for her hard work on this project. Again, I am thankful for having this experience, which has already helped me obtain other opportunities in my career. I hope the department continues to receive grants like so future undergraduates can have the ability to conduct research and improve their college experience at Idaho State University.



Idaho State University

Department of Civil and Environmental Engineering

Strength and Permeability of High Strength Pervious Concrete

S. Brandeberry and B. Murri

May 2023

Abstract

Pervious concrete is a type of concrete that has a high porosity and allows water to flow through it easily. This helps reduce the amount of water that enters stormwater systems, regulate flooding, specifically in urban areas, and allows for greater traction. The permeability of the concrete allows for the stormwater to percolate through the concrete and return to the groundwater. Additionally, because concrete is normally placed over a gravel base, the pervious concrete and gravel act as a retention area, providing natural bio-remediation to the polluted runoff improving water quality. Pervious concrete also has the potential to be used in pumped storage systems to store water as potential energy, one of the applications of this study. In this study, ultra-high-performance concrete (UHPC) was studied to determine how to increase the compressive strength of pervious concrete while maintaining permeability. UHPC is a cementitious mixture that has a minimum of 17,000 psi in compressive strength with additional requirements in durability and toughness. To test for the permeability of UHPC, five drainage channels (i.e. holes) were placed in cylindrical specimens and the change in compressive strength was recorded. Two variables that significantly influence the strength and durability of UHPC are supplementary cementitious materials (SCMs) and the addition of fibers. These factors were analyzed and included in the testing of traditional pervious concrete. Silica fume is an SCM that strengthens the bond between aggregates and was proven to be beneficial to pervious concrete mixes. The silica fume was included in the mix at varying percentages to determine the greatest compressive strength using this SCM. Polypropylene or steel fibers were then added to the optimal mix containing silica fume to determine the greatest compressive strength possible using a combination of these materials. The permeability of the concrete samples was measured using a modified falling head permeameter.

Table of Contents

Abstract	ii
Table of Contents	iii
List of Figures	v
List of Tables	vi
1. Introduction	1
1.1 Background	1
1.2 Purpose and Significance of Study	2
2. Literature Review	3
2.1 Literature on Ultra High Performance Concrete	3
2.1.1 Compressive Strength and Permeability of High-performance Concrete (Lü Jianfu, et al. (2011))	3
2.1.2 High Strength Clogging Resisting Permeable Pavement (Kia, Alalea, et al. (2019))	4
2.1.3 Defining clogging potential for permeable concrete (Kia, Alalea, et at. (2018))	8
2.1.4 Preparation and performance evaluation of an innovative pervious concrete pavement (Li, Jiusu, et al. (2017))	9
2.1.5 Fire Performance Of Ultra-High Performance Concrete (MacDougal, B., et al. (2021))	11
2.2 Literature on Traditional Pervious Concrete	12
2.2.1 Development of high-strength pervious concrete incorporated with high percentages of waste glass (Shen, P. et al. (2020))	12
2.2.2 An Integrated Study of Pervious Concrete Mixture Design for Wearing Course Applications (Schaefer, Vernon R. and Kevern, John T. (2011))	13
2.2.3 Effect of fly ash on the strength of porous concrete using recycled coarse aggregate to replace low-quality natural coarse aggregate (AIP Conference Proceedings (2017))	15
2.2.4 Developing High Strength Pervious Concrete Mixtures with Local Materials (Torres, A., Aguayo, F., Gaedicke, C., Nerby, P., Cavazos, M. and Nerby, C. (2020))	16
2.2.5 Development of High Quality Pervious Concrete Specifications for Maryland Conditions Summary (Amde, A. E., and S. Rogge. (2013))	17
2.2.6 Multi-criteria optimum mixture design of porous concrete pavement surface layers (Elizondo-Martinez, 2022)	18
2.2.7 Mix Design for Pervious Recycled Aggregate Concrete (Sriravindrarah, 2012)	20

2.2.8 Development of a sustainable pervious pavement material using recycled ceramic aggregate and bio-based polyurethane binder (Lu, 2019)	21
2.2.9 Mix Design Development for Pervious Concrete in Cold Weather Climates (Kever, 2014)	22
2.2.10 Compressive Strength of Light-Weight Concrete Material Made from Treated Wood Waste as a Coarse Aggregate (Alrubaie, 2023)	25
3. Methods and Materials	27
4. Results and Conclusions	31
Traditional Pervious Concrete	31
UHPC Pervious Concrete	34
5. References	36

List of Figures

Figure 1 Hole Design (Kia, 2019).....	5
Figure 2 Falling Head Permeability Apparatus (Kia, 2019)	6
Figure 3 Compressive and Flexural Strength (Kia, 2019)	7
Figure 4 Permeability and Porosity (Kia, 2019)	7
Figure 5 Compressive Strength and Porosity (Kia, 2018)	9
Figure 6 Hole Components (Li, 2017).....	10
Figure 7 Precast Design (Li, 2017)	10
Figure 8 Permeability Apparatus (Shen, 2020).....	13
Figure 9 Compressive Strength and Permeability (Schaefer, 2011)	14
Figure 10 Permeability to Void Ratio (Kever, 2014).....	23
Figure 11 7-day Compressive Strength (Kever, 2014)	24
Figure 12 Compressive Strength Results (Kever, 2014).....	24
Figure 13 Freeze-thaw Cycles (Kever, 2014)	25
Figure 14 Traditional Pervious Concrete Cylinder	27
Figure 15 Traditional Pervious Concrete Cylinder with Fibers	27
Figure 16 Pervious UHPC Cylinder.....	28
Figure 17 Method to Form Pervious UHPC	29
Figure 18 Falling Head Permeability Test Apparatus.....	29
Figure 19 Compressive Strength Test Apparatus.....	30
Figure 20 Solid Cement Layer	32
Figure 21 Traditional Pervious Concrete Fracture.....	33
Figure 22 Traditional Pervious Concrete with Fibers Fracture.....	33
Figure 23 Traditional Pervious Concrete with Fibers Loaded Laterally.....	33

List of Tables

Table 1 Test Results (Lü Jianfu, 2011)	4
Table 2 Mix Design (Kia, 2019)	5
Table 3 Optimal Mix (Li, 2017).....	11
Table 4 Testing Results (Schaefer, 2011)	15
Table 5 Mix Design (Elizondo-Martinez, 2022).....	18
Table 6 Mix Design Results (Elizondo-Martinez, 2022).....	19
Table 7 Mix Design Results (Sriravindrarajah, 2012)	21
Table 8 Mix Design (Lu, 2019)	22
Table 9 Group Mixes (Alrubaie, 2023).....	26
Table 10 Compressive Strength Results (Alrubaie, 2023).....	26
Table 11 Lab Developed UHPC Mix.....	28
Table 12 Traditional Pervious Concrete Results.....	31
Table 13 UHPC Results	34

1. Introduction

1.1 Background

Urban runoff and flooding have become an ever-growing issue in many urban areas. This issue is created by the lack of pervious surfaces within a city, prohibiting the natural water cycle from occurring. Naturally in undeveloped areas after a large storm event water is slowed down by vegetation and is allowed to soak through the ground into the aquifer. However, in developed areas due to buildings and pavement, stormwater is unable to drain and creates runoff. This water is usually diverted in stormwater drains flowing directly into streams carrying oil, plastic, wastes, and any other contaminants which were on the roads or parking lots. This is an obvious environmental issue but not the only issue with impervious surfaces. Higher likelihood of flooding is also associated with impervious concrete surfaces in urban areas. Since the water is unable to drain into the ground this can cause large buildup and overload storm drains, causing floods. Pervious concrete is a potential solution for these problems, since the concrete is porous in nature it allows water to flow through limiting runoff. Pervious concrete also acts as a filter that will replenish aquifers with clean water.

One difficulty in keeping pervious concrete from being widely used is its lower compressive strength and durability compared to normal strength impervious concrete. Due to the interconnected nature of the void spaces found in pervious concrete, compressive strength is significantly decreased. Ultra-high performance concrete (UHPC) utilizes a blend of fine-grained aggregates and chemical admixtures to vastly increase the strength and durability. The compressive strength of UHPC ranges from 18,000 psi to 22,000 psi. This is partly due to the use of fibers and a well-graded range of fine-grained elements. These fine-grained elements include the use of silica fume, a supplementary cementitious material (SCM). Silica fume increases the bond strength between aggregates when utilized in pervious concrete and fills remaining void spaces in UHPC due to the size of the silica fume particles. Steel fibers

are also included in UHPC to increase tensile strength. These fibers provide a network that increases post stress strength and allows the concrete to have a longer life span. UHPC is most commonly used in prestressed concrete girder simple-span bridges and between prefabricated bridge connections. These limited applications are primarily due to the higher costs of the material and installation associated with UHPC. The combination of factors in pervious and UHPC allow for a strengthened pervious concrete.

1.2 Purpose and Significance of Study

The purpose of this study is to develop a high strength pervious concrete to counteract the decrease in compressive strength. To find a solution to this issue, ultra-high performance concrete (UHPC) was studied to analyze the factors that increased the compressive strength found in UHPC. Possible applications for this study include the use of pervious concrete in urban roadways to decrease runoff. This also provides benefits to agricultural regions where runoff needs to be transported from downstream areas to provide water for crops. The decreased runoff would allow stormwater to return to the groundwater systems presently in place requiring less energy to be expended to deliver water to fields and irrigation systems. Other applications include the use of pervious concrete for energy storage. A parallel study at Idaho State University has analyzed and tested the use of manufactured pervious concrete to be placed within towers of rubber tires. These columns would allow for water to permeate through the concrete providing energy storage and strength within the aqueduct where the tire and concrete is placed. Other applications are feasible though they were not specifically analyzed during this study. Future research is required to accurately determine the uses of the findings in this study.

2. Literature Review

2.1 Literature on Ultra High Performance Concrete

2.1.1 Compressive Strength and Permeability of High-performance Concrete (Lü Jianfu, 2011)

The curing process is critical to the strength of high-performance concrete. Multiple curing processes were tested including a standard curing at 20 degrees C and relative humidity. Other methods included matched curing with the specimen in a sealed plastic membrane and matched curing of naked concrete where the specimen was in a temperature-controlled curing box. The effects on the strength and the permeability of the specimen were analyzed compared to the method of curing. This allows for an analysis relating to in-field curing and how to maximize the compressive strength.

The Concept: Curing is important in how the strength of concrete increases after being mixed. Two mixes were tested, and the difference between them was the amount of supplementary cementitious materials (SCMs) used. The first mix had no SCMs present while the second used a combination of fly ash and silica fume. The inclusion of SCMs increased the compressive strength in each of the curing conditions tested.

The Results: The curing method that had the greatest permeability was the standard curing process. Both the matched curing with a specimen in a sealed membrane and the matched curing of naked concrete in a curing box had greater compressive strength in a smaller curing time period. The values of the compressive strength and mix design are shown in Table 1.

Table 1 Test Results (Lü Jianfu, 2011)

Mix No.	w/c	Concrete composition/(kg/m ³)								Slump /mm
		Cement	Water	Fine aggregate	Coarse aggregate	Silicon fume	Fly ash	Air-entraining agent	Mighty100	
1	0.36	414	149	642	1195	—	—	—	2.89	170
2	0.36	311	149	642	1195	33.1	70.4	0.042	3.31	166

Table 3 Rapid chloride permeability and compressive strength of concrete

Mix No.	Curing condition	Charge passed/C		Compressive strength/MPa							
		56 d	480 d	1 d	3 d	7 d	14 d	28 d	56 d	248 d	
1	SC	1448.8	308.0	15.1	37.9	46.6	58.9	66.7	74.2	78.6	
2		320.8	190.0	11.2	29.4	42.9	57.5	71.8	74.0	82.8	
1	MC	458.4	324.0	27.5	55.0	60.8	66.5	69.2	71.2	72.5	
2		86.4	60.0	21.2	58.0	66.3	67.9	71.2	72.8	74.8	
1	NMC	558.0	360.0	29.7	58.5	69.8	73.7	75.6	76.1	77.2	
2		130.4	108.6	24.7	62.0	75.4	77.9	80.2	80.8	81.8	

The use of SCMs increases the compressive strength of cured concrete, though the results of this study show that the permeability has decreased significantly. This decrease was a result of the particle size of the SCMs utilized. This provided additional particle packing within the specimens which decreased the void spaces between particles.

2.1.2 High Strength Clogging Resisting Permeable Pavement (Kia, 2019)

Clogging of pores is a concern in pervious concrete. The void spaces between aggregate can become clogged due to time and the filtering of other materials including some materials from the concrete itself. Data was collected regarding the maintenance of compressive strength while increasing anti clogging.

The Concept: Traditional pervious concrete was tested, both a commercial mix and a newly designed clogging resistant mix. Mix designs are shown in Table 2. These mixes contained the conventional means of obtaining pervious concrete, so they contained large aggregates and cement. Another mix design was used that resembled ultra-high performance concrete, in that it used particle packing to create a dense structure capable of withstanding increased loads. This mix was made pervious

by using plastic tubes to make straight holes through the concrete for optimal flow. The design structure is shown in Figure 1.

Table 2 Mix Design (Kia, 2019)

Mix	No of tubes x diameter of tubes (mm)	Cement (kg/m ³)	Sand (kg/ m ³)	Water (kg/m ³)	SP (%)	w/c	Target porosity (%)
2% P	21 × 3	697	1297	278	0.25	0.4	2
4% P	42 × 3	683	1270	273	0.25	0.4	4
4% P*	11 × 6	683	1270	273	0.25	0.4	4
5% P	21 × 5	675	1257	270	0.25	0.4	5
8% P	84 × 3	654	1217	261	0.25	0.4	8
8% P*	21 × 6	654	1217	261	0.25	0.4	8
11% P	42 × 5	633	1177	253	0.25	0.4	11
15% P	42 × 6	604	1125	241	0.25	0.4	15
21% P	84 × 5	562	1045	224	0.25	0.4	21
30% P	84 × 6	498	926	199	0.25	0.4	30

*Mixes of similar porosity are differentiated by using an asterisk.

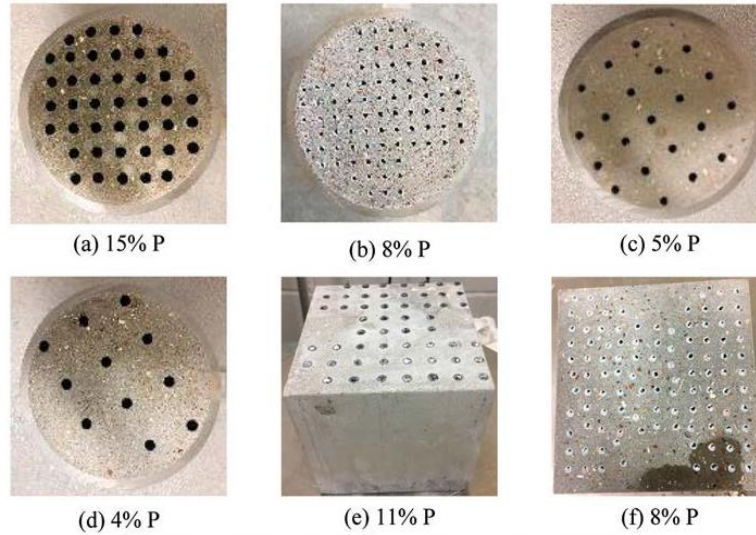


Figure 1 Hole Design (Kia, 2019)

The permeability test was performed using a falling head permeability test. The height difference was 750mm. Figure 2 shows the falling head permeability test setup.

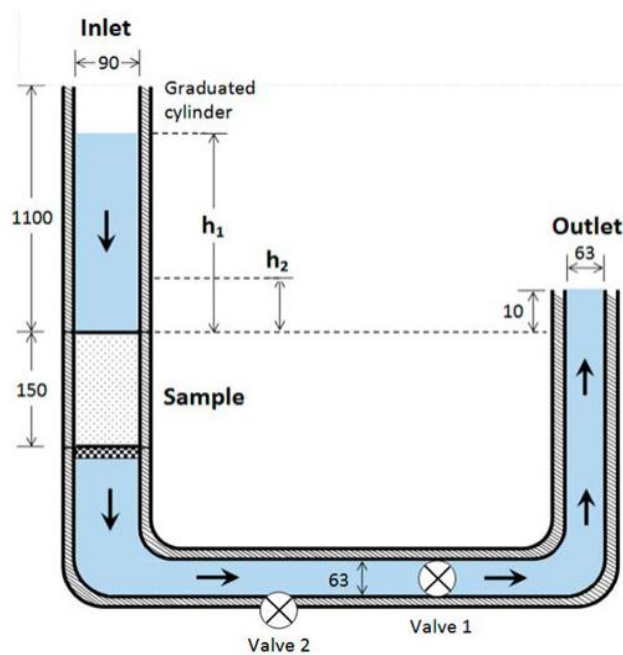


Figure 2 Falling Head Permeability Apparatus (Kia, 2019)

The Results: The use of plastic straws to form straight holes in the concrete significantly decreased the resultant clogging. This was due to the interlocking void spaces of traditional pervious concrete having winding properties which allowed for buildup of other materials. The use of holes in ultra-high performance concrete is beneficial, especially while considering permeable concrete uses. Few studies have been conducted regarding this method and no workable field tests have been conducted. The compressive strength of the concrete was related to the porosity and this is shown in Figure 3.

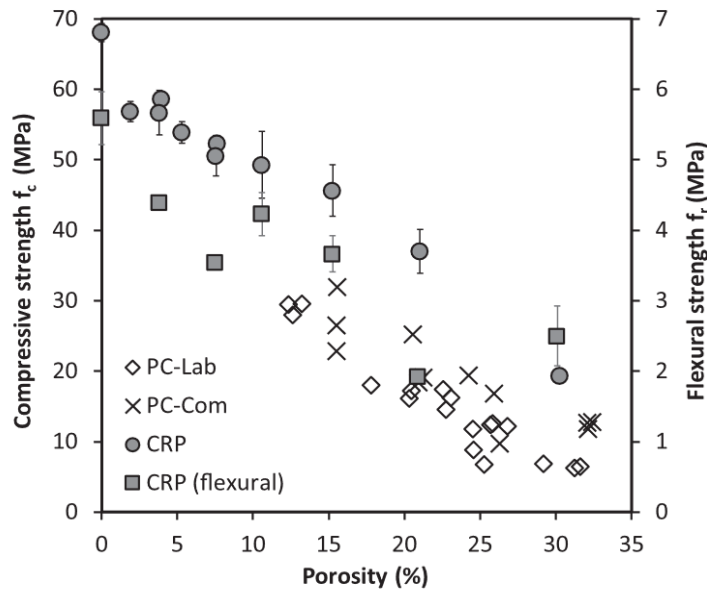


Figure 3 Compressive and Flexural Strength (Kia, 2019)

The study shows that porosity and permeability are directly related. This relationship is shown in Figure 4. The study shows the benefits of using the high strength concrete over the traditional pervious concrete. On both Figure 3 and Figure 4 the CRP is the anti-clogging high strength mix that was developed in the laboratory.

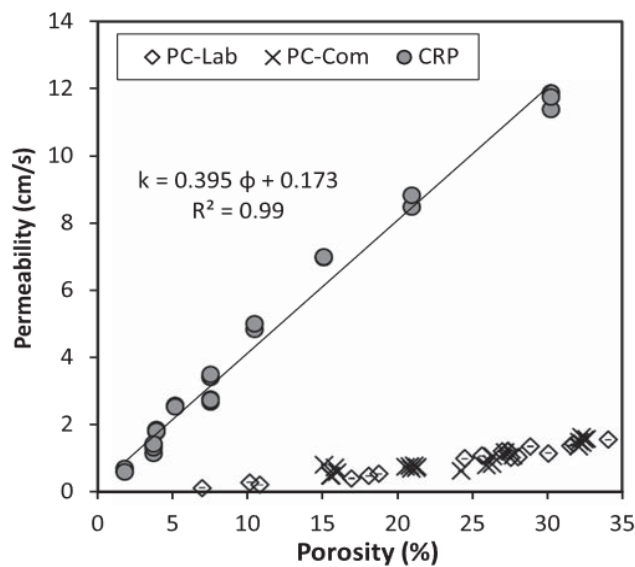


Figure 4 Permeability and Porosity (Kia, 2019)

2.1.3 Defining Clogging Potential for Permeable Concrete (Kia, 2018)

In traditional pervious concrete, void spaces between aggregate can become clogged due to time and the filtering of other materials including some materials from the concrete itself. Data was collected regarding the maintenance of compressive strength while increasing anti clogging. Variables were tested relating to particle size, type, and the effective porosity.

The Concepts: The falling heads permeability test was performed to analyze the effects of clogging. Sand and/or clay material was added to the specimens when they were in the apparatus to determine how efficiently they avoided clogging. This test was performed until the specimen became impermeable and no water would pass through the apparatus.

The Results: The compressive strength decreased approximately 4% for every 1% increase in porosity. This relationship is shown in Figure 5. The permeability of the concrete was found to be greater in pervious concrete containing larger aggregate sizes; however, these specimens were also found to clog easily. This is due to the greater tortuosity of the samples allowing for a greater buildup and collection of the added materials. The increasing pressure due to changes in the head, led to a decreased permeability due to the friction from the turbulent water. The mixes using high strength concrete with holes were found to be beneficial though not in a significant way.

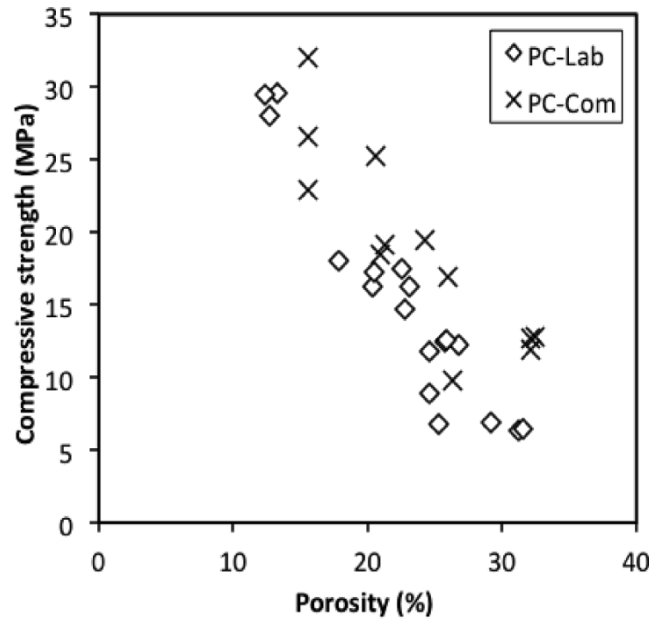


Figure 5 Compressive Strength and Porosity (Kia, 2018)

2.1.4 Preparation and performance evaluation of an innovative pervious concrete pavement (Li, 2017)

Ultra-high performance concrete (UHPC) uses supplementary cementitious materials (SCMs) such as silica fume and fly ash to aid in the particle packing that gives UHPC its strength. Some mixes also contain an expansion agent with strong resistance to undesirable shrinkage that often contains aluminum sulfate, aluminum oxide and aluminum potassium sulfate. Other additives include a superplasticizer or high range water reducer (HRWR).

The Concepts: Pore making rods were inserted into the UHPC mixes and the concrete was allowed to cure. This design structure is shown in Figure 6. Pore design limited tortuosity. Different amounts of rods were placed to test for the effects of compressive strength regarding permeability. Preliminary designs were created to analyze the use of permeable UHPC in precast concrete. The precast design concept is shown in Figure 7.

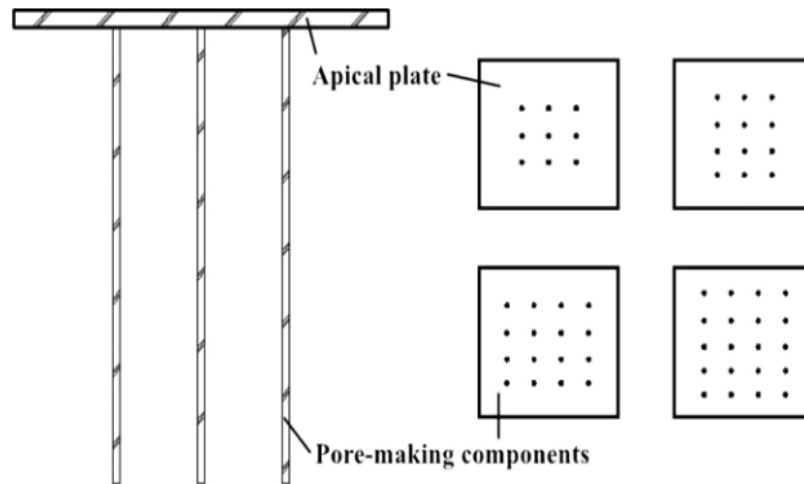


Figure 6 Hole Components (Li, 2017)

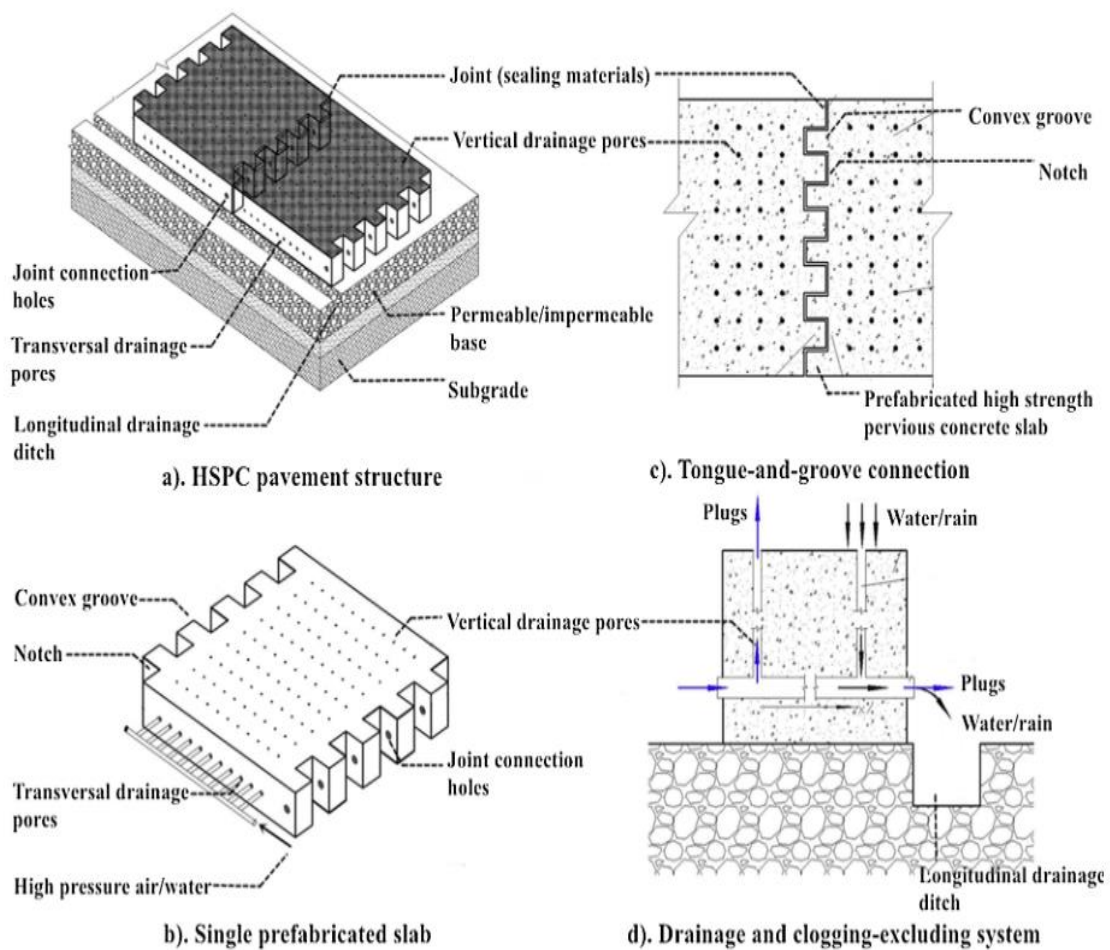


Figure 7 Precast Design (Li, 2017)

The Results: Optimum mix results reached 70 MPa under natural curing conditions and 80 MPa under constant curing conditions. This optimal mix is shown in Table 3. The tensile strength found reached 10 MPa with low strength reduction. Permeability increased with the addition of rods to create additional holes in the UHPC. The change in permeability was not significant to not warrant use of less rods. In addition, the use of additional holes did not significantly decrease the compressive strength; however, the compressive strength did decrease.

Table 3 Optimal Mix (Li, 2017)

Optimum mix proportion of HSPC.

P.O 52.5R	FA	SF	Sand	UEA	Superplasticizer	PP	Silica gel	SBR	Water
100%	11.83%	5.92%	46.75%	3.00%	1.36%	0.08%	0.70%	1.30%	28.44%

2.1.5 Fire Performance of Ultra-High Performance Concrete (MacDougall, B., et al. (2021))

Ultra-high performance concrete (UHPC) is a workable and dense concrete that is susceptible to explosive spalling when brought in contact with elevated temperatures. Explosive spalling is found when a fire is present and the delaminated surface of concrete peels away in an explosive manner that results in greater damage.

The Concepts: Factors used to create UHPC were analyzed to see the effectiveness of those factors in decreasing the likelihood of explosive spalling. Micro-steel fibers have the greatest impact on the strength of the specimen including maintaining structural integrity. The particle packing used to increase compressive strength in UHPC proved difficult as no void spaces were created. The stress from spalling was held by the particles themselves instead of within the voids found in traditional concrete.

The Results: The use of steel fibers did not decrease the likelihood of spalling, though replacing these fibers with polypropylene fibers proved to be beneficial. The polypropylene fibers melted when exposed to high temperatures and provided void spaces where internal stresses were released. Other

options were also considered, such as adding in larger aggregate to provide a greater matrix in which internal stresses could dissipate. The optimum use of fibers was found to be in between 1-3.5% of the mix. The compressive strength of specimens containing polypropylene fibers was less than the compressive strength of specimens containing steel fibers. A hybrid mix containing both fibers was deemed the optimal mix.

2.2 Literature on Traditional Pervious Concrete

2.2.1 Development of high-strength pervious concrete incorporated with high percentages of waste glass (Shen, 2020)

Due to an overabundance of waste glass in Hong Kong, Shep P., et al, study how to replace natural aggregate with waste glass (WG) aggregate to solve the lack of natural aggregates in the area. This study analyzes how using waste glass weakens traditional pervious concrete while increasing the risk of alkali silica reactions (ASR) and how to counteract these results.

The Concept: Waste glass particles being used as both an aggregate and a supplementary cementitious material (SCM) increase the effects of ASR. To counteract this reaction, silica fume is added as an additional SCM. Silica fume, combined with Portland cement, creates a high-performance concrete paste. Silica fume also increases the bonding between aggregates. Additional fibers also prove beneficial to prevent ASR due to mechanical confinement. The natural porous structure of pervious concrete will mitigate ASR due to the interconnecting voids. These combined elements of pervious concrete, silica fume, fibers, and a porous structure, will allow those in Hong Kong to replace natural aggregates with waste glass aggregates while maintaining strength and durability. Permeability was tested using an adjusted falling head as shown in Figure 8.

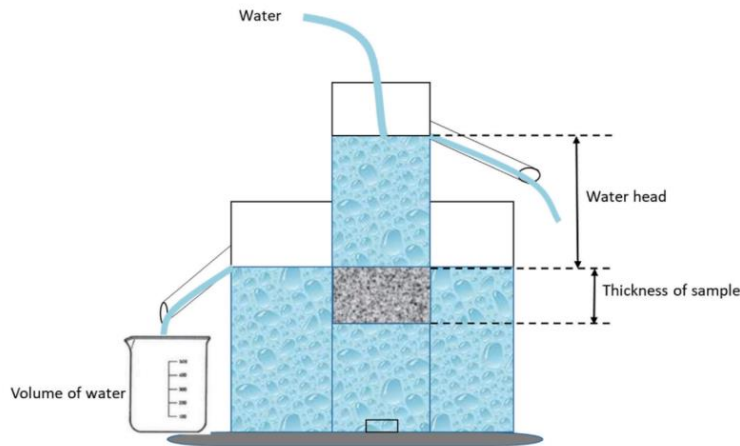


Figure 8 Permeability Apparatus (Shen, 2020)

The Results: Each test specimen had a compressive strength greater than 2,466 psi, which was the desired amount. The waste glass led to higher permeability with a lower density. This was attributed to the smooth surfaces of the waste glass aggregate allowing for less tortuosity within the specimens. The ASR expansion effects were mitigated, in part, by using SCMs and partly by the porous structure of the sample allowing for internal stresses and expansion to be transferred to void spaces.

2.2.2 An Integrated Study of Pervious Concrete Mixture Design for Wearing Course Applications (Schaefer, 2011)

Water content significantly impacts the compressive strength, permeability, and freeze-thaw durability in pervious concrete. The size of aggregate will also affect the permeability.

The Concepts: Typical water to cement ratios range between 0.27-0.4 and result in a strength between 800-3000 psi. Various aggregate types will also impact the strength of the concrete. Rounded aggregates have better results related to the binding between aggregates. Permeability is also an important factor when analyzing the strength of pervious concrete. This can be tested using a flexible sealing gum around the outside of the specimen with a rubber sleeve to remain confined and allow the water to flow through the sample.

The Results: The relationship between porosity and compressive strength shows that the greater the void spaces within the specimen, the less compressive strength will be possible. The addition of 5-7% sand was able to provide additional strength, though the void spaces between aggregates were decreased. The greater the water content, the greater the workability but the overall performance is reduced. The water to cement ratio was narrowed to between 0.27-0.33. The optimal mix had a mixture of slag and fly ash for supplementary cementitious materials and included 10% of fine aggregate or sand. The relationship between compressive strength and permeability is shown in Figure 9, while the values from this study are found in Table 4.

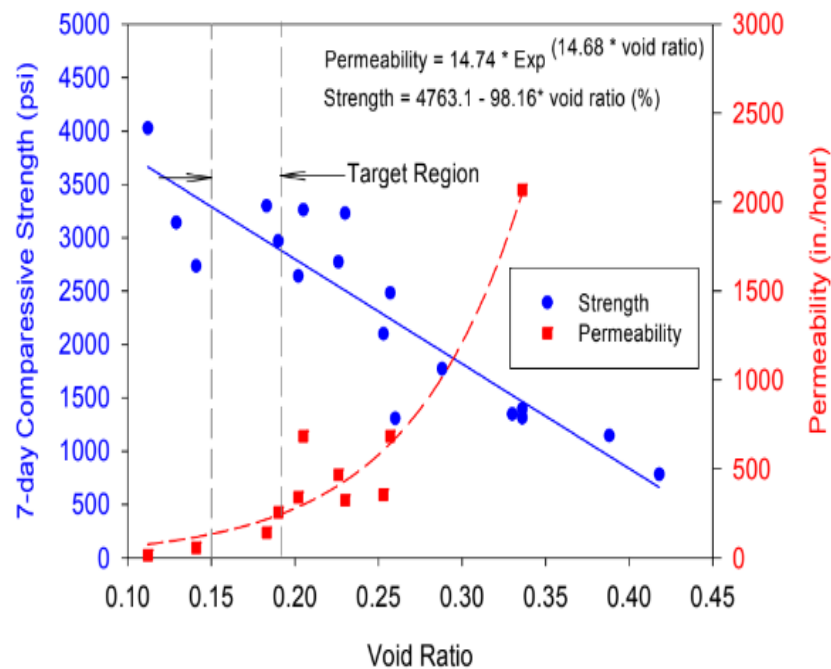


Figure 9 Compressive Strength and Permeability (Schaefer, 2011)

Table 4 Testing Results (Schaefer, 2011)

Mixture	Porosity (%)	Unit Weight kg/m ³ (lb/ft ³)	28-day Compressive Strength MPa (psi)	28-day Splitting Tensile Strength MPa (psi)	Permeability cm/hr (in./hr)
PG	27.0	1,920 (120)	16.1 (2,340)	1.95 (280)	3,492 (1,375)
PG-N1	23.0	1,980 (124)	23.0 (3,340)	2.30 (340)	1,116 (439)
PG-N2	20.7	1,990 (124)	24.4 (3,530)	2.85 (410)	720 (283)
PG-S1	21.2	2,000 (125)	23.0 (3,340)	2.30 (335)	216 (85)
PG-S2	15.3	2,070 (129)	23.8 (3,450)	2.40 (345)	72 (28)
LS	32.6	1,720 (108)	15.1 (2,190)	1.60 (230)	3,672 (1,446)
LS-N1	31.7	1,710 (107)	13.9 (2,020)	1.40 (205)	2,844 (1,120)
LS-N2	31.1	1,740 (109)	11.3 (1,650)	1.30 (185)	2,664 (1,049)
LS-S1	25.9	1,710 (107)	12.0 (1,740)	1.50 (215)	1,584 (624)
LS-S2	24.7	1,720 (107)	9.6 (1,390)	1.70 (245)	900 (354)

PG=pea gravel, LS=limestone, N=natural AEA, S=synthetic AEA

2.2.3 Effect of fly ash on the strength of porous concrete using recycled coarse aggregate to replace low-quality natural coarse aggregate (AIP Conference Proceedings (2017))

The aggregate present in pervious concrete comes from various sources depending on the area of manufacture. The use of recycled aggregates can prove beneficial and could replace low quality natural coarse aggregates. Recycled aggregates are known to have greater permeability than natural aggregates as well.

The Concepts: Fly ash improves durability in concrete as well as workability. Thus, a mixture of fly ash and cement creates a binder for a mix containing either natural coarse aggregate or recycled coarse aggregate. From previous studies, the water to cement ratio was 0.3 for every mixture tested.

The Results: The compressive strength of the pervious concrete increased with the density of the concrete, though the density of the porous concrete varied too greatly to make conclusive comparisons. An increase in strength was shown with the use of fly ash that was a result of the pozzolanic reaction within the fly ash to create a dense and impervious paste. The optimal mix for compressive strength

contained 25% fly ash as a replacement for cement and 75% of the total aggregate containing recycled aggregate. The optimal tensile strength, at 220.5 psi, was found to be in the same mix as the greatest compressive strength.

2.2.4 Developing High Strength Pervious Concrete Mixtures with Local Materials (Torres, A., 2020)

This study analyzed how additives were used to provide a strong permeable surface. These additives were analyzed alongside local materials such as aggregate. No polymers present in pervious concrete have been explored previously. Superplasticizer is another additive that has proved beneficial to pervious concrete mixes. The addition of an excessive amount of superplasticizer can be detrimental as the mortar will conglomerate at the bottom of the sample creating an impervious barrier.

The Concepts: A systematic approach was taken to determine an optimal mix, testing variables of aggregate shape and size, water to cement ratio, and silica fume replacement. Each variable was tested with everything else held constant, the optimal compressive strength was then used in testing of the next variable.

The Results: The first variable tested was size and shape of the aggregate; the smaller 6.35 mm rounded gravel was shown to be the strongest. This is because it allows tighter packing, and a stronger bond. Next, the water content was tested and a water to cement ratio of 0.28 performed the best. Lastly, silica fume replacement of cement was tested up to 30%, which also performed the best. The porosity and percolation rates were also taken and were acceptable for all mixtures, they ranged from 19.1% - 32.9% for porosity and 1.9mm/s - 5.8mm/s for percolation rate.

2.2.5 Development of High Quality Pervious Concrete Specifications for Maryland Conditions Summary (Amde, A. E., 2013)

This study set out to find advantages and disadvantages of certain admixtures to pervious concrete. The study was funded by the Maryland State Highway Administration (SHA) thus the main purpose of this was to develop a concrete which would be suitable for highways, specifically the for SHA projects.

The Concept: Different admixtures were tested to find advantages including cellulose fibers, a delayed set modifier, and a viscosity modifier. Samples with these admixtures were tested for density, porosity, compressive strength, split tensile strength, permeability, freeze-thaw durability, and abrasion resistance. ASTM C1688 was used to determine density and void content, ASTM C496 was used to determine tensile strength, ASTM C666 was used to determine freeze thaw durability, and ASTM C944 was used to determine the abrasion resistance.

The Results: Do you mean this: The use of Viscosity Modifier Admixture prevents the cement from flowing to the bottom of the mix, thus preventing formation of an impermeable layer. This is when the cement flows to the bottom and essentially makes an impermeable surface. The addition of a Viscosity Modifier Admixture didn't have much impact on the strength or durability of the concrete. Cellulose fibers proved to work well as a replacement to polypropylene fibers, they contribute to reduction in shrinkage and temperature cracking, and fiber balling. However, they are not resistant to alkaline or other fungi and algae attacks. Delayed Set Modifiers resulted in a more fluid mix, but needs to be used carefully or it can create an impervious layer at the bottom of concrete.

2.2.6 Multi-criteria optimum mixture design of porous concrete pavement surface layers (Elizondo-Martinez, 2022)

This study sets out to find an optimum mix for porous concrete on a widespread basis. Many porous mixtures are dependent on materials that are found in their local areas. This study allows for principles to be used across a wide variety of factors involved in mix design.

The concept: The use of aggregate within porous concrete is vital. The recommendation was to not include aggregate greater than 1/2“ as larger aggregates have greater difficulty adhering to the cementitious material and will weaken the overall strength on the concrete. Table 5 shows the mix designs tested. Variables included the aggregate size, water content, and the silica to cement ratio.

Table 5 Mix Design (Elizondo-Martinez, 2022)

Mixture code (a-b-c-d) *	AG (mm)	s/c	w/c	Cement (kg/m3)	VMA (%)
30-0-A-I	2-4	0.00	0.30	397.23	44.30
40-0-A-I	2-4	0.00	0.40	341.48	44.30
30-1-A-I	2-4	1.00	0.30	255.15	44.30
40-1-A-I	2-4	1.00	0.40	230.92	44.30
30-0-B-I	4-8	0.00	0.30	397.23	44.30
35-0-B-I	4-8	0.00	0.35	367.23	44.30
40-0-B-I	4-8	0.00	0.40	341.48	44.30
30-5-B-I	4-8	0.50	0.30	310.71	44.30
35-5-B-I	4-8	0.50	0.35	292.05	44.30
40-5-B-I	4-8	0.50	0.40	275.52	44.30
30-1-B-I	4-8	1.00	0.30	255.15	44.30
35-1-B-I	4-8	1.00	0.35	242.42	44.30
40-1-B-I	4-8	1.00	0.40	230.92	44.30
30-0-B-II	4-8	0.00	0.30	440.81	47.00
35-0-B-II	4-8	0.00	0.35	407.54	47.00
40-0-B-II	4-8	0.00	0.40	378.94	47.00
40-1-B-II	4-8	1.00	0.40	256.27	47.00
30-1-B-II	4-8	1.00	0.30	283.15	47.00
35-5-B-II	4-8	0.50	0.35	324.12	47.00
30-5-B-II	4-8	0.50	0.30	344.81	47.00
40-5-B-II	4-8	0.50	0.40	305.76	47.00
30-0-C-I	4-12	0.00	0.30	397.23	44.30
40-0-C-I	4-12	0.00	0.40	341.48	44.30
30-1-C-I	4-12	1.00	0.30	255.15	44.30
40-1-C-I	4-12	1.00	0.40	230.92	44.30
30-0-C-II	4-12	0.00	0.30	440.81	47.00
40-1-C-II	4-12	1.00	0.40	256.28	47.00
30-0-D-I	8-12	0.00	0.30	397.23	44.30
40-0-D-I	8-12	0.00	0.40	341.48	44.30
30-1-D-I	8-12	1.00	0.30	255.15	44.30
40-1-D-I	8-12	1.00	0.40	230.92	44.30

The Results: This study found that the smaller aggregates (0.08-0.16”) did have a large percentage of void space, but less permeability. This is most likely due to the lack of voids being interconnected. Mix 30-5-B-II was seen to be the best since it had the greatest compressive strength while also having a permeability to control general storm situations. The best conditions found in the trends tested were that 4-8mm aggregates (0.16-0.31”) had the best compressive strength while the voids located within were able to be connected. Table 6 shows the results of the tests completed, including the tensile and compressive strengths.

Table 6 Mix Design Results (Elizondo-Martinez, 2022)

Mixture	AV (%)	σ	IT (MPa)	σ	k (cm/s)	σ	CS (MPa)	σ	BPN dry	σ	BPN wet	σ	Stiffness Modulus (MPa)	σ
30-0-A-I	21.86	0.01	1.47	0.09	0.19	0.02	16.70	1.63	75.00	0.00	65.00	1.07	18256.50	374.00
40-0-A-I	21.82	0.01	1.43	0.10	0.40	0.03	16.70	1.13	70.00	0.93	61.00	4.64	17627.50	3027.00
30-1-A-I	23.60	0.01	1.20	0.16	0.22	0.06	9.17	1.42	69.00	1.00	61.00	5.74	15318.50	144.00
40-1-A-I	23.27	0.01	1.44	0.15	0.23	0.03	14.00	0.90	63.00	1.67	55.00	5.48	17435.50	292.00
30-0-B-I	22.58	0.01	1.37	0.12	0.54	0.07	12.45	2.73	73.00	2.07	63.00	3.74	17038.50	647.00
35-0-B-I	23.17	0.01	1.43	0.14	0.58	0.09	15.15	2.38	67.00	15.03	50.00	4.17	19199.00	278.00
40-0-B-I	20.35	0.01	1.39	0.19	0.43	0.07	15.60	2.56	73.00	1.12	66.00	0.79	19077.00	416.00
30-5-B-I	22.89	0.00	1.51	0.15	0.48	0.07	14.55	1.72	66.00	1.19	59.00	1.00	21360.50	726.00
35-5-B-I	22.68	0.00	1.74	0.06	0.70	0.17	15.85	1.73	72.00	1.63	62.00	5.00	21087.00	29.00
40-5-B-I	23.76	0.01	1.49	0.10	0.71	0.12	14.45	2.83	68.00	4.16	59.00	2.50	19183.00	1204.00
30-1-B-I	23.16	0.01	1.69	0.23	0.54	0.06	18.15	1.88	68.00	2.93	58.00	7.11	18762.00	799.00
35-1-B-I	23.73	0.01	1.28	0.22	0.57	0.04	13.40	1.27	70.00	2.83	64.00	0.92	17985.00	211.00
40-1-B-I	19.76	0.01	1.41	0.10	0.42	0.03	14.90	0.70	85.00	0.53	80.00	4.75	18662.00	1543.00
30-0-B-II	23.14	0.01	1.57	0.15	0.37	0.11	16.10	3.03	64.00	4.33	54.00	3.21	17846.00	899.00
35-0-B-II	23.09	0.01	1.54	0.11	0.50	0.12	16.50	3.93	68.00	4.12	55.00	11.50	19401.00	1315.00
40-0-B-II	25.00	0.01	1.63	0.26	0.48	0.14	15.75	1.96	57.00	1.66	53.00	1.89	21921.00	4531.00
40-1-B-II	22.15	0.01	1.44	0.09	0.56	0.03	14.00	2.91	70.00	0.98	62.00	3.26	19260.50	2404.00
30-1-B-II	24.53	0.01	1.13	0.10	0.51	0.25	8.01	0.52	61.00	6.15	57.00	4.03	16683.00	1097.00
35-5-B-II	20.92	0.00	1.65	0.11	0.20	0.11	18.27	4.91	75.00	4.47	65.00	5.51	19195.00	2727.00
30-5-B-II	22.07	0.01	1.89	0.06	0.23	0.05	18.80	3.66	73.00	1.36	58.00	2.25	17899.00	1523.00
40-5-B-II	24.33	0.01	1.83	0.10	0.42	0.03	15.10	0.90	65.00	5.45	59.00	6.96	18431.50	142.00
30-0-C-I	21.14	0.01	1.37	0.05	0.60	0.06	12.60	3.33	80.00	0.00	61.00	0.52	17198.00	726.00
40-0-C-I	22.42	0.01	1.19	0.16	0.88	0.16	8.80	0.65	71.00	0.52	57.00	4.30	14146.00	1506.00
30-1-C-I	23.14	0.01	1.30	0.11	0.67	0.19	10.90	1.20	68.00	5.00	58.00	2.48	15195.50	558.00
40-1-C-I	23.48	0.01	1.44	0.26	0.87	0.13	12.80	2.42	65.00	0.00	55.00	3.96	14712.50	1924.00
30-0-C-II	22.15	0.01	1.69	0.20	0.41	0.15	14.60	2.97	69.00	0.96	61.00	2.80	16564.50	299.00
40-1-C-II	21.15	0.01	1.49	0.11	0.52	0.18	14.70	3.07	86.00	0.55	80.00	6.57	18855.00	2697.00
30-0-D-I	24.34	0.00	1.38	0.28	1.00	0.27	11.85	1.76	60.00	5.92	55.00	5.85	16547.50	313.00
40-0-D-I	24.57	0.01	1.10	0.05	1.40	0.05	7.88	0.73	64.00	9.09	52.00	2.76	11154.50	661.00
30-1-D-I	24.31	0.02	1.10	0.12	0.67	0.01	8.35	0.86	65.00	2.73	55.00	3.62	20838.00	7531.00
40-1-D-I	25.10	0.02	0.92	0.08	1.90	0.02	5.14	0.59	65.00	5.25	59.00	0.76	13478.00	1227.00

Sand was also tested to determine the effect on the friction for roadways. The increase in sand led to greater friction as it increased the surface area of the specimen tested. The relationship between sand and voids contained was used to demonstrate how this is caused. Higher amounts of sand than 5% were found to lead to greater clogging on the surface and pooling water, which will decrease the friction. They determined .35 w/c as the permeability tended to be greater and some samples exhibited high compressive

strengths. Viscosity modifying admixtures were tested and they were determined to improve adhesion and friction between aggregates. This enabled larger percentages of mortar in the mixtures.

2.2.7 Mix Design for Pervious Recycled Aggregate Concrete (Sriravindrarajah, 2012)

Due to the location where pervious concrete is being mixed, different local materials are often used for aggregate. This comes with the material type that is commonly found and available in the area as well as the size and shape of the materials available. Recycled aggregate is often tested as it is directly correlated to a decrease in compressive strength and often a decrease in permeability as well, though recycled aggregate is often less expensive and more readily available making it a viable alternative if a mix design is successful in meeting criteria.

The Concept: This study set out to find how age, aggregate type, size, and shape affect the strength of the concrete and porosity. For aggregate type they used natural and recycled coarse aggregate at sizes of 20 and 13 mm in cylinders and cubes. For binder type they used Portland cement and ground granulated blast furnace slag. For age they tested the specimens at 7 and 28 days. In the study they performed a falling head permeability test and a destructive compression test.

Results: This study found that the variables tested have a slight impact on permeability and compressive strength, but ultimately the biggest impact was due to the porosity of the concrete. The shape

of the test specimen did not show to have an impact. Table 7 shows the results of the 28-day strength as well as the porosity of the samples tested.

2.2.8 Development of a sustainable pervious pavement material using recycled ceramic aggregate and bio-based polyurethane binder (Lu, 2019)

This study was conducted to develop permeable asphalt using crushed old ceramic as the aggregate and a bio-based polyurethane (PU) as the binder. Referred to as PU-bound Ceramics Recycled (Porous) Pavement or PCRCP.

Table 7 Mix Design Results (Sriravindrarajah, 2012)

Mix	Age (days)	Porosity range (%)	28-Day strength f_{28} range (MPa)	Mean porosity (%)	Mean 28-day strength (MPa)	Strength ratio (f_{28}/f_7)
NA20	7	30.9–36.7	6.16–8.53	42.1	7.41	1.00
	28	33.3–36.1	6.69–7.79	34.3	7.41	1.00
NA13	7	25.5–29.3	11.1–13.1	27.7	11.8	1.00
	28	26.8–28.1	12.0–15.8	27.5	13.9	1.18
RA20	7	23.5–25.4	6.03–6.80	27.7	6.47	1.00
	28	24.6–28.8	4.48–6.96	27.5	6.06	0.94
RA13	7	13.8–16.1	6.42–12.1	14.4	11.1	1.00
	28	7.0–13.2	10.4–13.3	9.87	12.1	1.09
RA13S35	7	22.1–27.0	4.99–6.81	24.4	5.79	1.00
	28	22.8–28.4	5.09–7.00	25.5	6.19	1.07
RA13S70	7	13.7–16.0	8.55–10.8	15.0	10.0	1.00
	28	13.9–19.7	10.2–11.1	16.7	10.6	1.06

The Concept: The materials used for the ceramic was crushed toilet and bathroom demolition waste. This accounted for 70% of the total aggregate at sizes ranging from 2.0-5.6 mm and the other 30% was natural sand. Conventional permeable asphalt or PA with 8 mm maximum aggregate size was used as reference. A uniaxial compression test, uniaxial cyclic compression test, dynamic indirect tensile test, polishing test, falling head permeability test, and an acoustic test were performed on the samples. Table 8 shows the variables tested including grain size and materials used.

Results: A cost analysis was performed to determine that the PCRCP was \$144.5/ton more expensive than conventional permeable asphalt mainly because of the cost of the polyurethane binder. However, PCRCP also had favorable benefits. From the uniaxial compression test, the PCRCP performed better than the PA by twice as much from the uniaxial cyclic compression test. Furthermore, the PCRCP

could withstand 10 times as much loadings as the conventional PA. From the indirect tensile test its shown that the fatigue behavior is similar. From the polishing test the conventional PA seems to have much more loss in mass over time than PRCP. From the permeability test the PRCP has close to three times as much permeability with similar void content than the conventional PA. From the acoustic test the PRCP has a similar absorption coefficient than that of PA at 1000 Hz, but for PRCP the coefficient stays high over a larger frequency range. Meaning that the PRCP can absorb much more noise than that of conventional PA.

Table 8 Mix Design (Lu, 2019)

Mix design of PCRCP and PA 8 mixture.

PCRCP Materials	Grain size (mm)	Mass percentage (%)	Apparent density (g/cm ³)	PA8 Materials	Grain size (mm)	Mass percentage (%)	Apparent density (g/cm ³)
Sand	0–0.063	5.0	2.850	Limestone	0–0.063	5.0	2.820
	0.063–2	10.0	2.850		0.063–2	15.0	2.820
Ceramic	0.063–2	10.0	2.434	Diabase	2–5.6	37.0	2.820
	2–5.6	52.0	2.434		5.6–8	43.0	2.820
	5.6–8	23.0	2.434				
Polyurethane	2-component Polyurethane, 6.5 M-%		1.09	Bitumen	Polymer modified bitumen 40/100-65 A, 6.5 M-%		1.472
PCRCP Mixtures	Air void content 28.5 vol.-%		2.34	PA Mixture	Air void content 26.2 vol.-%		2.541

2.2.9 Mix Design Development for Pervious Concrete in Cold Weather Climates (Kever, 2014)

Portland cement is a common component in pervious concrete mix design. This study sets out to find a mix that maintains porosity while increasing the freeze-thaw durability of the concrete itself.

The Concept: The typical mix of pervious concrete generally contains no sand or fine aggregate and a w/c ratio between 0.27-0.43. The compressive strength is then normally below 3000 psi which is the lower limit for structural concrete. This study mixed various admixtures, fine aggregates percentages, and supplementary cementitious materials to test for strength after 7 days. The best results were then tested for long term durability, freeze-thaw resistance, and permeability. Styrene butadiene rubber (SBR) latex was added to improve aggregate bonding. Those mixes that didn't include the SBR contained an air entraining agent or high-range water reducer.

The Results: Based on the void ratio and the strength of the specimens tested during the 7-day trial, mixes containing aggregate from $\frac{3}{8}$ " - No. 4 proved to have the greatest compressive strength. The study shows that adding 7% of sand increased strength from 57-84%. This also reduced voids by approximately 8% decreasing permeability. The relationship between permeability and void space is shown in Figure 10 The permeability decreased from an average of .5 in/s to .19 in/s. This is also shown in Figure 11. Test results showed that approximately 10% of latex was determined to be the appropriate percentage to add to the mix to improve workability and compressive strength. The point of failure was in the cement paste when larger aggregates were used. The compressive strength results are recorded in Figure 12.

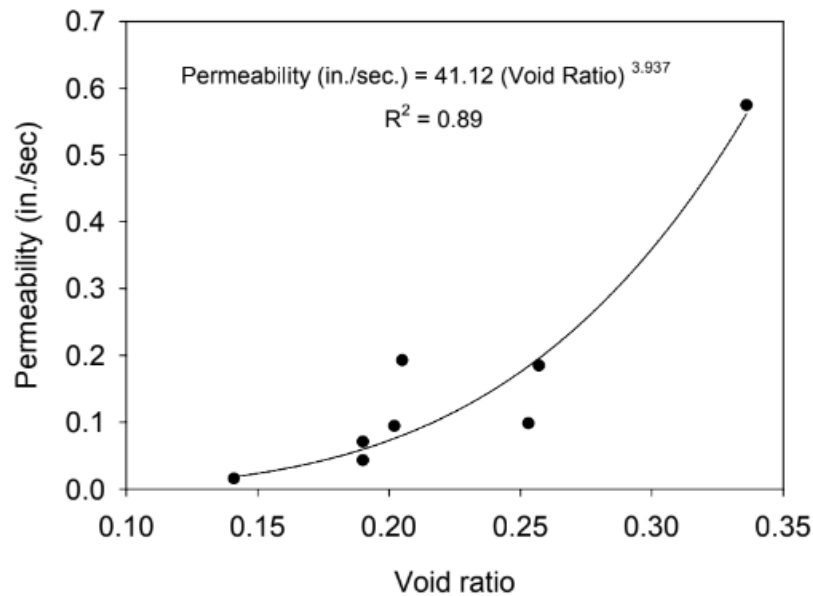


Figure 10 Permeability to Void Ratio (Kever, 2014)

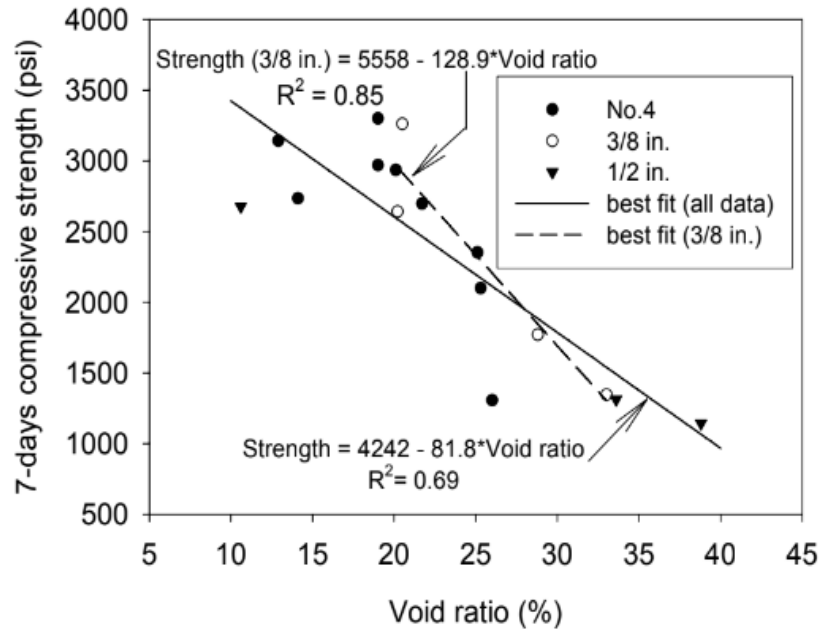


Figure 11 7-day Compressive Strength (Kever, 2014)

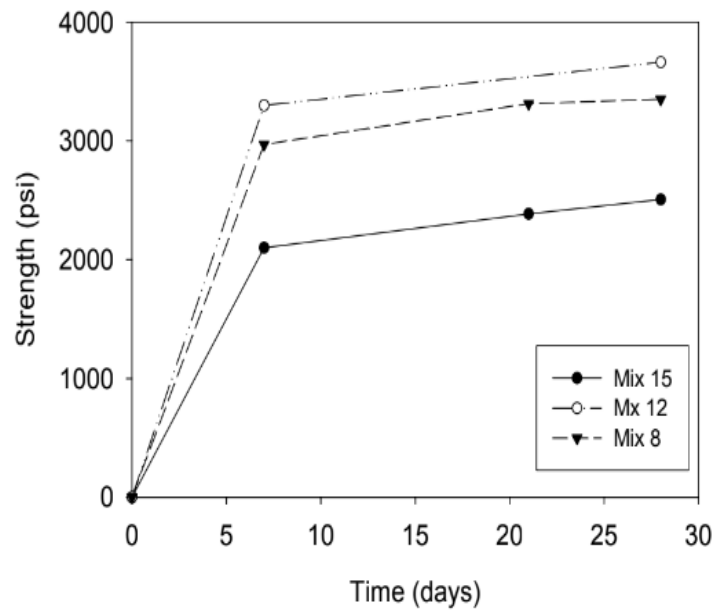


Figure 12 Compressive Strength Results (Kever, 2014)

Results showed that river gravel provided greater compressive strength as an aggregate than crushed limestone. The smaller aggregate was also seen to provide greater strength but a decreased void ratio. Sand improved compressive strength. Sand with latex showed no significant changes in specimen

results. The mixes tested all showed less than a 6% loss after 180 freeze-thaw cycles. The freeze-thaw results are displayed in Figure 13.

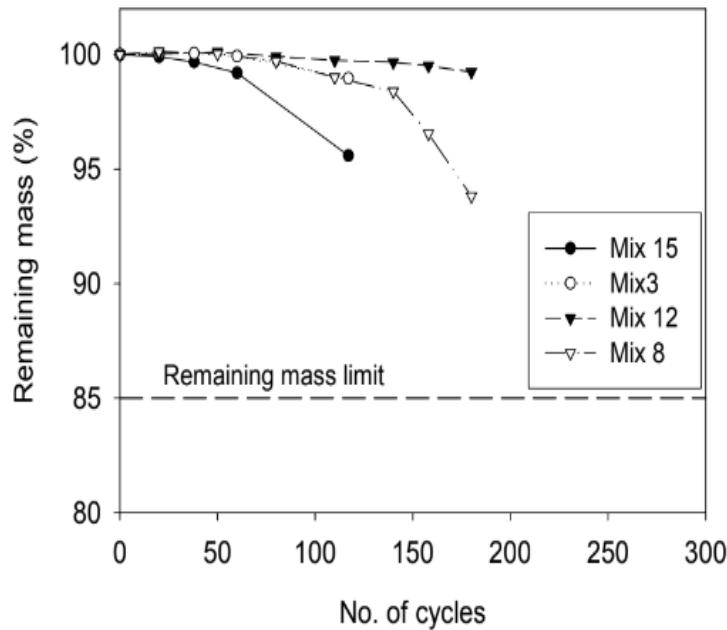


Figure 13 Freeze-thaw Cycles (Kever, 2014)

2.2.10 Compressive Strength of Light-Weight Concrete Material Made from Treated Wood Waste as a Coarse Aggregate (Alrubaie, 2023)

This study explores the use of wood waste in concrete. The benefits of using wood include affordability and sustainability, especially in construction.

The Concept: Previous studies were analyzed and found that if the wood replaced over 7.5% of the aggregate, the strength was decreased in a manner that resulted in the compressive strength being below the required limit. The max size for the coarse aggregate used was 10 mm, with the smallest being just below 4.75mm. The wood was treated by being coated with a cement paste and tile adhesive mix. This was left to dry for 16 days. Emulsifiers were included in some of the samples tested to slow down the loss of hydration during the curing process. The groups tested are shown in Table 9.

Table 9 Group Mixes (Alrubaie, 2023)

Group Numbering	Acronym/Specimens-Label/Group Name	Description
Group-1	NC-CTRL1	Control mix of normal concrete that contains natural coarse aggregate
Group-2	TW-CTRL2	Control mix of normal concrete that contains 100% replacement of natural coarse aggregate with untreated-raw wood shavings
Group-3	CBTW-NE	Cement-based treated-coated wood shavings without emulsifier
Group-4	CBTW-WE	Cement-based treated-coated wood shavings with emulsifier
Group-5	ABTW-NE	Adhesive-based treated-coated wood shavings without emulsifier
Group-6	ABTW-WE	Adhesive-based treated-coated wood shavings with emulsifier

The Results: The slump test had results that showed a slump of less than 45mm which is seen to have a low workability. The concrete made with wood waste had significantly less compressive strength as well. Compressive strength of the various groups is shown in Table 10.

Table 10 Compressive Strength Results (Alrubaie, 2023)

Group Name	Compressive Strength (MPa)					
	Cubes (Size 1)	CV (%)	Cubes (Size 2)	CV (%)	Cylinder (Size 3)	CV (%)
NC-CTRL1	39.63	3.31	39.54	2.52	39.5	3.18
TW-CTRL2	9.26	4.14	9.90	3.86	8.40	6.17
CBTW-NE	12.08	5.19	18.45	0.38	12.7	3.40
CBTW-WE	14.19	8.16	18.20	0.78	13.90	5.23
ABTW-NE	8.59	7.54	11.90	2.38	10.10	3.65
ABTW-WE	10.48	3.63	10.20	0.00	10.40	9.76

This study used a w/c ratio of 0.5, and the specimens containing the emulsifier did have greater slump, though it was still beneath 45mm. The uptake of water was tested, and the wood waste that was coated resulted in decreased water uptake compared to the uncoated wood. Water uptake can be related to the resultant permeability of the concrete; however, this study shows that the replacement of wood waste does not provide greater permeability with a resultant porous concrete. The concrete produced could not be used for the structural purposes it was intended for, but the results did fulfill ASTM requirements to be used in roadways.

3. Methods and Materials

This research took two different directions to develop high strength pervious concrete. The first approach was a more traditional one where the fine aggregate in the concrete was removed creating a porous structure which allowed water to flow through. Figure 14 and Figure 15 show the porous structure that the specimens contained. In this method six different mixes were made with variables being the aggregate size ($\frac{1}{4}$ inch, $\frac{3}{8}$ inch) and admixtures including high range water reducer (HRWR), silica fume replacement (20%, 30%, 40%), and polypropylene fibers (0 oz, 1.5 oz, 3 oz). The mix with the optimum percentage of silica fume replacement was used to test the addition of polypropylene fibers.



Figure 14 Traditional Pervious Concrete Cylinder



Figure 15 Traditional Pervious Concrete Cylinder with Fibers

The second approach was to create holes in UHPC using 1/8 inch steel rods. Here two mixes were created, one proprietary from Ductal and the other from a lab developed UHPC mix at Idaho State University as shown in Table 11. For both mixes, six cylindrical specimens were prepared to allow water to permeate. A typical pervious UHPC specimen is shown in Figure 16.

Table 11 Lab Developed UHPC Mix

Item	Amount (lb)	Percent passing FVR 1
Water	300	100
HRWR	65	100
Portland Cement	1300	99
Silica Fume	246	61
Fly Ash	371	33
Fine Aggregate	1557	12
Steel Fiber	263	0



Figure 16 Pervious UHPC Cylinder

This was done by inserting 5 1/8 inch steel rods inside of the UHPC cylinders, as shown in Figure 17, allowing the concrete to set for 2 hours, then removing the rods. All of the mixes were allowed to initially set for 24 hours in 3 inch DIA. x 6 inch molds, removed, then cured for 28 days.



Figure 17 Method to Form Pervious UHPC

A falling head permeability test was also performed to determine the infiltration rate of the concrete. The apparatus used is shown in Figure 18. The optimum mix with each of the variables were determined using these tests. Standard ASTM Compressive strength tests were carried out on all the mixes with the exception of increased loading rate on the UHPC specimens. The increased loading rate is recommended by the modified ASTM compression strength test. Both tests were performed using the compressive strength test apparatus shown in Figure 19.



Figure 18 Falling Head Permeability Test Apparatus



Figure 19 Compressive Strength Test Apparatus

4. Results and Conclusions

Traditional Pervious Concrete

The compressive strength of the traditional pervious concrete mixtures gradually increased with the addition of silica fume and polypropylene fibers. Silica fume replacement increased by 10% from 20% up to 40%, showing improvement to compressive strength with more silica fume. These results are shown in Table 12.

Table 12 Traditional Pervious Concrete Results

Mix #	Silica Fume (%)	Polypropylene Fibers (oz)	Average Compressive Strength (psi)	Average Permeability Coefficient (in/s)
1	0.2	0	210	1.121
2	0.2	0	307	1.034
3	0.2	0	263	1.015
4	0.3	0	562	0.989
5	0.4	3	985	0.201
6	0.4	1.5	1,329	0.219

Data from Mix 1 and Mix 2 were compared to determine the size of aggregate to use, Mix 1 using $\frac{1}{4}$ inch aggregate and Mix 2 using $\frac{3}{8}$ inch aggregate. The $\frac{3}{8}$ inch mix had a higher compressive strength, contrary to literature, but because of these findings and availability the $\frac{3}{8}$ inch aggregate was used for the rest of the study.

Polypropylene fibers were also tested adding 0 oz, 1.5 oz and 3 oz. The addition in moderation showed to help compressive strength, with the optimal for a 0.041 ft^3 batch being the addition of 1.5 oz of polypropylene fibers. It is important to note that the two batches using polypropylene fibers also included High Range Water Reducer (HRWR) in the amount of 0.35 lbs in order to achieve our intended

w/c ratio. The HRWR was added because the mixes continued to be too dry, and this was our solution to achieve a workable mix without adding excess water. HRWR needs to be used with a light hand though, or the cement in the mix will flow to the bottom of the cylinder and create an impervious surface. An example of this mix is shown in Figure 20.

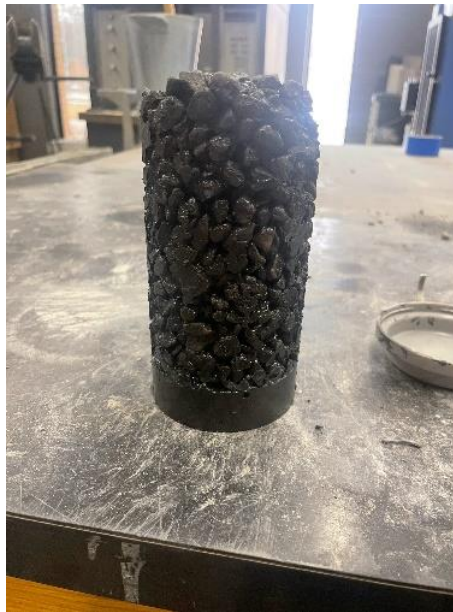


Figure 20 Solid Cement Layer

An interesting note to consider with the addition of fibers is their ability to hold the specimens together. After failure the specimens did not seem to be broken and held their structure instead of crumbling like the other mixes. Figure 21 shows the specimens that crumbled after failure, while Figure 22 shows a specimen that held its structure after failure. Even if loaded laterally the cylinder would hold together with deformation as shown in Figure 23. Although we had limited data it seemed that the samples with fibers would hold at least 50% of their strength after initial fracture unlike others which would hold almost no force.



Figure 21 Traditional Pervious Concrete Fracture



Figure 22 Traditional Pervious Concrete with Fibers Fracture



Figure 23 Traditional Pervious Concrete with Fibers Loaded Laterally

Overall mix 6 for the traditional pervious concrete was the optimal mix with a 40% silica fume replacement of cement and 1.5 oz of polypropylene fibers. The average compressive strength was 1,329 psi with an average permeability of 0.219 in/s.

UHPC Pervious Concrete

The compressive strength of the UHPC was much higher than traditional pervious concrete with the average compressive strength of the Lab Mix with Holes holding over 7 times the pressure that the strongest traditional pervious concrete mix could hold. The results for the UHPC are found in Table 13. The addition of holes into the UHPC cylinders on average only decreased the compressive strength by 12.7% showing that if needed more holes could be added to increase permeability while keeping adequate strength.

Table 13 UHPC Results

Mix	Average Compressive Strength (psi)	Average Permeability Coefficient (in/s)
Proprietary No Holes	16,415	N/A
Proprietary with Holes	14,154	0.344
Lab Mix No Holes	10,922	N/A
Lab Mix with Holes	9,652	0.219

The proprietary mix with holes held on average 4,500 psi more than the lab mix, however 9,600 psi for concrete is more than enough strength for most applications. The lab developed mix was also significantly less expensive because it is not patented and can be made with local materials.

UHPC however has the additive fly ash which is considered to be a hazardous chemical and its involvement in pervious concrete could prove to be a problem with introducing it into the groundwater

system. More research needs to be done to see the possible impacts, and if this could be removed and have sufficient strength.

Each of the pervious mixes resulted in a permeability greater than the standard pervious mixes utilized in the field today and all can withstand a 100-year storm event in most of the world. The resultant compressive strength for traditional pervious concrete was significantly decreased than that used in practice. The use of UHPC with steel rods inserted has proven to be most beneficial as the permeability results were all greater than the standard amount for stormwater in most of the world and has a compressive strength higher than almost all conventional concrete. A more practical way of implementing pervious UHPC in the field still needs to be studied.

5. References

- AIP Conference Proceedings **1887**, 020055 (2017); <https://doi.org/10.1063/1.5003538> Published Online: 29 September 2017.
- Alrubaie et al. (2023). “Lightweight concrete strength,” *BioResources* 18(1), 111-130. DOI: 10.15376/biores.18.1.111-130
- Amde, A. E., and S. Rogge. *DEVELOPMENT OF HIGH QUALITY PERVIOUS CONCRETE SPECIFICATIONS FOR MARYLAND CONDITIONS*. Feb. 2013, https://www.roads.maryland.gov/OPR_Research/MD-13-SP009B4F_Pervious-Concrete-Specifications_Report.pdf.
- E. J. Elizondo-Martínez, V. C. Andrés-Valeri, L. Juli-Gándara & J. Rodríguez-Hernandez (2022) Multi-criteria optimum mixture design of porous concrete pavement surface layers, *International Journal of Pavement Engineering*, 23:3, 745-754, DOI: 10.1080/10298436.2020.1768254
- Kever, John, et al (2014). Mix Design Development for Pervious Concrete in Cold Weather Climates. *Proceedings of the 2005 Mid-Continent Transportation Research Symposium, Ames, Iowa, August 2005*.
- Kia, Alalea, et al. “High-Strength Clogging Resistant Permeable Pavement.” *International Journal of Pavement Engineering*, vol. 22, no. 3, 2019, pp. 271–282., <https://doi.org/10.1080/10298436.2019.1600693>.
- Kia, Alalea, et al. “Defining Clogging Potential for Permeable Concrete.” *Journal of Environmental Management*, vol. 220, 2018, pp. 44–53., <https://doi.org/10.1016/j.jenvman.2018.05.016>.
- Li, Jiusu, et al. “Preparation and Performance Evaluation of an Innovative Pervious Concrete Pavement.” *Construction and Building Materials*, vol. 138, 2017, pp. 479–485., <https://doi.org/10.1016/j.conbuildmat.2017.01.137>.

- Lu, Guoyang, et al. "Development of a Sustainable Pervious Pavement Material Using Recycled Ceramic Aggregate and Bio-Based Polyurethane Binder." *Journal of Cleaner Production*, vol. 220, 2019, pp. 1052–1060., <https://doi.org/10.1016/j.jclepro.2019.02.184>.
- Lü Jianfu, et al. (2011). Compressive Strength and Permeability of High-Performance Concrete. *Journal of Wuhan University of Technology-Mater. Sci. Ed*, (Feb. 2011). 10.1007/s11595-011-0185-5.
- MacDougall, B., et al (2021). Fire Performance of Ultra-High Performance concrete. *CSCE 2021 Annual Conference, Department of Civil Engineering, Queen's University, Kingston, K7L 3N6, Canada*
Carleton University, Department of Civil and Environmental Engineering, 1125 Colonel By Drive, Ottawa, K1S 5B6, Canada. 17bnm2@queensu.ca_
- Schaefer, Vernon R. and Kevern, John T. (2011). "An Integrated Study of Pervious Concrete Mixture Design for Wearing Course Applications." *National Concrete Pavement Technology Center, DTFH61-06-H-00011*.
- Shen P., et al (2020). Development of high-strength pervious concrete incorporated with high percentages of waste glass. *Elsevier*, 114. <http://www.elsevier.com/locate/cemconcomp>
- Sriravindrarajah, Rasiah, et al. "Mix Design for Pervious Recycled Aggregate Concrete." *International Journal of Concrete Structures and Materials*, vol. 6, no. 4, 2012, pp. 239–246., <https://doi.org/10.1007/s40069-012-0024-x>.
- Torres, A., Aguayo, F., Gaedicke, C., Nerby, P., Cavazos, M. and Nerby, C. (2020) Developing High Strength Pervious Concrete Mixtures with Local Materials. *Journal of Materials Science and Chemical Engineering*, 8, 20-34.

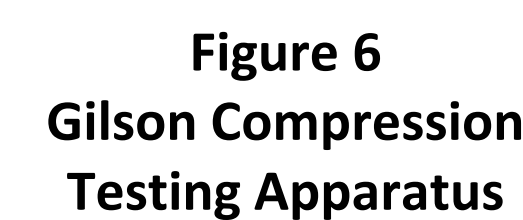
Abstract

Objectives

- ## Methods

- Figure 2**
Traditional Pervious Concrete with Fibers

Methods Continued



Results



Additional Testing Regarding High Strength Pervious Concrete Is Underway

Results Continued



- ## Discussion/Conclusions

- Acknowledgements:** Thanks to ISU Civil and Environmental Department for the use of facilities and materials. Thanks to Dr. Ebrahimpour, Dr. Savage, and Katie Hogarth for the support and guidance throughout this project.

Final Report: Office for Research – SBOE Undergraduate Research Funding

Date: November 16, 2023

PI: Anirban Chakraborty

Co-PI: Julia E. Martin

Project: Investigation of spore-forming anaerobic bacteria in untreated wastewater samples from Southeastern Idaho

Part 1

Description of Activities Undertaken: The research team comprised of three undergraduate research interns (URI) – Abigail Gallegos, Diana Rivas and Douglas Madlock, in the Department of Biological Sciences. The team investigated viable, spore-forming anaerobic bacteria in influent wastewater samples obtained from three wastewater treatment plants located in Pocatello, Blackfoot, and Soda Springs in the Southeastern Idaho. Each URI led the experimental activities using samples from one of the above locations and performed laboratory growth assays aimed to enrich. The URIs presented their findings in poster presentations at the Department of Biological Science's Biology Research Roundup in Spring 2023. The research activities accomplished the project goals outlined in the proposal and generated valuable preliminary data that we will aim to incorporate in future publications and external grant proposals.

The PI and the CO-PI trained the URIs on various microbiological and molecular biological tools such as anoxic cultivation techniques, microbial growth assessment and metabolite measurement using UV-VIS spectrophotometry, visualization of microbial cells using phase-contrast microscopy and genomic DNA extraction for gene-based community analysis. The URS conducted month-long incubation experiments to enrich anaerobic, spore-forming bacteria at two different temperatures and using two different liquid growth media. The experiments were subsampled at two-to-three-day intervals and microbial growth was assessed. Furthermore, accumulation of specific metabolites characteristic of anaerobic growth was measured in the experimental subsamples. Finally, genomic DNA from enrichment cultures from different time points was extracted for molecular analysis.

At the beginning of the project in Fall 2022, the PI and the Co-PI established a mentoring plan consisting of mutual expectations for the mentors and mentees. Mentoring activities consisted of regular meeting of the PI and the Co-PI with the URIs, laboratory safety training, hands-on training on laboratory techniques and data analysis, discussion on research articles and on scientific communication. The URIs also routinely interacted with other research personnel (graduate students and other undergraduate students) in the PI's and the Co-PI's labs. Furthermore, the URIs attended the Biological Sciences Seminar Series as well as other public research presentations such as graduate student proposals and thesis defenses. These activities engaged the students with the departmental research community.

The PIs and the URIs completed the CITI Responsible Conduct of Research training as a requirement of this project. In addition, all project personnel completed several biosafety training modules including General Biosafety and Bloodborne Pathogens. Throughout this project, the URIs also gained experience on several aspects of teamwork such clear communication and helping each other in accomplishing project goals, professional

cooperation and contributing towards a healthy and respectful environment in the workplace. The URIs also participated in lab cleaning endeavors.

How the Project Benefitted from the Funds: This grant supported three URIs and two microbiology faculties in the Department of Biological Sciences and resulted in valuable data collection that will contribute to future research projects and collaborations involving the PI's and the Co-PI's respective research groups.

The funds supported salaries for three URIs including two women one of whom belongs to a historically underrepresented group in STEM. This project was the first ever research experience for two of the URIs and this would not be possible without the financial support from the SBOE HERC funds. We also used a small portion of the funding for procuring reagents for molecular analyses.

The project has aided the research productivity of PI Chakraborty, an early career faculty member (Assistant Professor) in the Department of Biological Sciences and has allowed Chakraborty to collaborate for the first time with Co-PI Martin, another microbiology faculty in the department. The research activities led by the URIs produced a valuable preliminary dataset as part of a larger long-running research theme within the Chakraborty Lab on the ecophysiology of anaerobic, spore-forming bacteria. The findings from this project will culminate into published research products and they will help in preparing proposals for future research activities.

How the Research Goals of the Project were Furthered: PI Chakraborty has been studying anaerobic, spore-forming bacteria from marine environments for close to a decade. The SBOE HERC funding enabled our team, for the first time, to investigate a different habitat, the wastewater, as a potential source of similar microorganisms. This work would not have been possible without funding due to time and financial constraints for the undergraduate researchers and for the PIs. The funds primarily supported hourly wages for the URIs since no additional funds were available to support wages for these researchers to complete their research activities.

A major logistical challenge in overseeing this project was to find suitable times when all three URIs could be available to meet either for hands-on training on a lab technique or for research-related discussions with the PIs. This was primarily due to their different class schedules being full-time students and often they could only meet with the PIs after the regular working hours. Therefore, it took much longer than expected to get the URIs trained on necessary laboratory techniques, some of which takes repeated trials to master, before they were ready to begin the growth experiments. We had initially estimated that the students will be able to present the findings of the molecular assays used in the project in their posters, however, that was not possible due to the delay in obtaining the experimental subsamples from the growth experiments. While the URIs really liked conducting the molecular assays such as genomic DNA extraction, it was disappointing for them since they wanted to include those results as part of their poster presentations. Additionally, one of the two growth media used in the experiments did not yield expected results and was not successful in fueling bacterial growth in any of the temperatures tested. In the future, I will be more cognizant in designing student-led experiments by incorporating a more realistic timeframe for training undergraduate researchers during academic semesters.

Part 2: Student Reports

SBOE 2023 Undergraduate Intern - Report for ISU's Office for Research

Project: Investigation of spore-forming anaerobic bacteria in untreated wastewater samples from Southeastern Idaho

Faculty Lead & Mentor: Dr. Julia Martin and Dr. Anirban Chakraborty

Student Name: Diana Rivas

Date: 11/13/2023

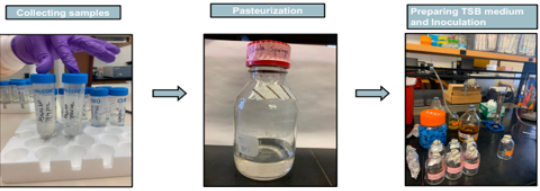
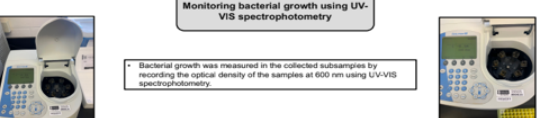
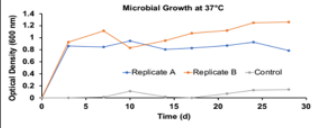
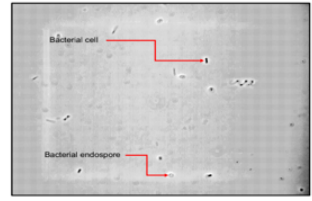
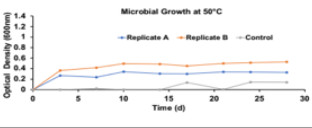
- 1. What did you learn from your internship experience?**
 - I learned how to use a spectrophotometer, and why we need to use it to measure bacterial growth at different temperatures.
- 2. How did this research experience benefit you?**
 - Having more lab skills will benefit me in applying for different research labs.
- 3. How has this research experience changed your future plans, if at all?**
 - I acquire new skills and knowledge, which allow me to pursue different interests, develop problem-solving abilities, and challenge myself.
 -

Spore-forming bacteria in influent wastewater collected from the Soda Springs Treatment Plant in Southeastern Idaho

Diana Rivas (rivadian@isu.edu), Julia E. Martin and Anirban Chakraborty
Department of Biological Sciences, Idaho State University, Pocatello, Idaho



Idaho State
University

BACKGROUND	METHODS	RESULTS
To thrive in hostile environments, some microorganisms are uniquely adapted to transform themselves into dormant structures, called endospores, as a survival strategy. Endospores are layered structures which are highly resistant to disinfection and sterilization methods and are essential to conserve the cell's genetic material under extreme stress (1). Several pathogenic bacteria responsible for foodborne diseases are also capable of forming spores. Wastewater plant treatments are essential to humans and animals to remove bacteria, liquids, or metals, prevent environmental pollution, and ensure drinking water safety for humans and animal consumption (2). Endospores are also found in untreated urban wastewater which is nutrient-rich and harbors a microbial community that is highly diverse. Wastewater treatment plants often utilize anaerobic bacteria for degrading complex organic matter and to produce biogas. However, the diversity of endospore-forming anaerobic bacteria in untreated wastewater has yet to be investigated in detail. The objective of this study was to enrich viable, spore-forming anaerobic bacteria at two different temperatures from untreated wastewater collected from the Soda Springs Wastewater Treatment Plant in southeastern Idaho.	Sample collection, Pasteurization, and Preparation of Tryptic Soy Broth (TSB) Medium  - Diluted Water (DI water) was used to setting the water bath at 80°C for 1 hour (this step was important to performed to eliminated any present bacteria that were not endospores) 250 ml of wastewater was combined from smaller containers in a single sterile, 500 ml Duran bottle - We labeled using a temporary label, using the name of the bottle sample 15 grams of Tryptic Soy Broth was added into 500 ml DI water - We used 90% Nitrogen (N₂) and 10% Carbon dioxide (CO₂) gas mixture to exchange the headspace and immediately sealed the bottles with sterile rubber stoppers Incubation at two temperatures (37°C and 50°C) and Subsampling procedure  - At each temperature, two replicate bottles were inoculated with wastewater and a third bottle was used as uninoculated control - Bottles were incubated for 28 days, subsamples were collected at three- and four-day intervals - Subsamples were collected using N₂-flushed syringes and needles - Within 10 days of incubation, inoculated bottles became turbid and had a strong odor, likely due to microbial growth and gas production Monitoring bacterial growth using UV-VIS spectrophotometry  - Bacterial growth was measured in the collected subsamples by recording the optical density of the samples at 600 nm using UV-VIS spectrophotometry.	Microbial Growth at 37°C  Figure 1: Growth of mesophilic bacteria at 37 °C in pasteurized incubation bottles. Phase Contrast Microscopy  Figure 1A: Bacterial cells and endospores in a subsample collected from the incubation bottles. Microbial Growth at 50°C  Figure 2: Growth of thermophilic bacteria at 50 °C in pasteurized incubation bottles.
CONCLUSION		
- Endospore-forming bacteria were present in the untreated wastewater from the Soda Springs Wastewater Treatment Plant - Microbial growth was observed at both temperatures tested - The growth at 37°C was more pronounced than the growth at 50°C - Visualization of endospores using phase-contrast microscopy confirmed their presence in the inoculation bottles		
FUTURE WORK		
DNA-based microbial community analysis will help identify the dominant community members in the enrichments.		
REFERENCES		
- Hubert, C.; Loy, A.; Nickle, M.; Arnosti, C.; Baranyi, C.; Bruchert, V.; Ferdelman, T.; Finster, K.; Christensen, F.M.; Rosa de Rezende, J.; Vandieken, V.; Jorgensen, B.B. "A Constant Flux of Diverse Thermophilic Bacteria into the Cold Arctic Seabed". <i>Science</i>, 325(2009). - Know your H2O (Water Research Center) "Get Informed Sulfate-Reducing Bacteria".		
ACKNOWLEDGMENT		
We thank Soda Springs Wastewater treatment plant for providing our samples. We thank Dr. Heather Ray for assistance with microscopy. Finally, we acknowledge funding from FY23		

SBOE 2023 Undergraduate Intern - Report for ISU's Office for Research

Project: Investigation of spore-forming anaerobic bacteria in untreated
wastewater samples from Southeastern Idaho

Faculty Lead & Mentor: Dr. Chakraborty and Dr. Martin

Student Name: Abigail Gallegos

Date: 11/11/23

1. What did you learn from your internship experience?

- I learned about how endospores can be incubated with specific gas. Use of gas tanks and needles to provide the samples with the desired gas environment was an incredible experience. I learned how to safely handle and dispose of needles as well as how to properly provide the sample bottles with new gas. I also learned how to use a Thermo Scientific Spectrophotometer, which I found very fascinating.

2. How did this research experience benefit you?

- I found this research beneficial in expanding my skills in the lab. I became comfortable and confident handling the gas needle. I also became confident in using the spectrophotometer and recording the results it provided. This experience overall gave me more familiarity with new tools and helped with my adaptability in the lab.

3. How has this research experience changed your future plans, if at all?

- This experience did not necessarily change my future plans for my career but did provide some insight into other possibilities. Presentation of the project did push me to try and expand on better visualization for the poster.

Enrichment of Anaerobic, Endospore-forming Bacteria using Untreated Wastewater from Blackfoot, Southeast Idaho

Abigail Gallegos (abigailgallegos@isu.edu), Julia Martin and Anirban Chakraborty
Department of Biological Sciences, Idaho State University, Pocatello, Idaho



Idaho State
University

Introduction

Urban wastewater is typically a mixed fluid consisting of effluents from various sources such as residential sewage, industrial waste, and stormwater runoff. The untreated wastewater is nutrient-rich and harbors a microbial community that is highly diverse (1). Wastewater treatment plants often utilize anaerobic bacteria for degrading complex organic matter and to produce biogas (2). Some anaerobic bacteria, however, produce harmful, toxic gases such as hydrogen sulfide (3). Many of these harmful bacteria are also uniquely adapted to survive harsh environmental conditions by transforming active cells into endospores (4). Bacterial spores are dormant, layered structures that protect the cell's genetic material when environments are unsuitable for growth and are therefore more resilient to disinfection and sterilization methods (4 & 5). Several pathogenic bacteria responsible for foodborne diseases are also capable of forming spores (6). However, the diversity of endospore-forming anaerobic bacteria in untreated wastewater has yet to be investigated in detail. The objective of this study was to enrich viable, spore-forming anaerobic bacteria at two different temperatures from untreated wastewater collected from the Blackfoot Wastewater Treatment Plant in southeastern Idaho.

Conclusions

- Endospore-forming bacteria were present in the untreated wastewater from the Blackfoot Wastewater Treatment Plant
- Microbial growth was observed at both temperatures tested
- The growth at 37°C was more pronounced than the growth at 50°C
- Visualization of endospores using phase-contrast microscopy confirmed their presence in the incubation bottles

Future Work

DNA-based microbial community analysis will help identify the dominant community members in the enrichments.

References

1. Smetacek, Peter. "Microbial Ecology." In: The Microbes, 10th ed. Elsevier, 2019. 101-120.
2. Smetacek, Peter. "Microbial Ecology." In: The Microbes, 10th ed. Elsevier, 2019. 101-120.
3. Smetacek, Peter. "Microbial Ecology." In: The Microbes, 10th ed. Elsevier, 2019. 101-120.
4. Smetacek, Peter. "Microbial Ecology." In: The Microbes, 10th ed. Elsevier, 2019. 101-120.
5. Smetacek, Peter. "Microbial Ecology." In: The Microbes, 10th ed. Elsevier, 2019. 101-120.
6. Smetacek, Peter. "Microbial Ecology." In: The Microbes, 10th ed. Elsevier, 2019. 101-120.

Acknowledgements

We thank the Blackfoot Wastewater Treatment Plant for providing our samples. We thank Dr. Heather Ray for assistance with microscopy. Funds are acknowledged from the P2020 SBIR grant.

Methods

1 Collection of Samples

Untreated wastewater samples from the Blackfoot WTP were combined in a sterile Duran bottle to accumulate a volume of 200 mL. The combined sample was stored at 4°C.

2 Pasteurization

The wastewater sample was pasteurized using a water bath at 80°C for one hour. Subsequently, after cooling the headspace was exchanged with N_2 gas for one minute and immediately sealed with a rubber stopper.

Medium Preparation: Selective for Fermentative Bacteria

Separately, anaerobic Tryptic Soy Broth (TSB) was prepared. The media bottles were sealed with a blue butyl rubber stopper and crimp. The headspace was then exchanged with N_2/CO_2 gas. The medium was autoclaved, and the headspace was exchanged again with N_2/CO_2 .

4 Inoculation

A set of three serum bottles with 40 mL of TSB was prepared for each incubation temperature. Two of the three bottles were inoculated with 10 mL of pasteurized wastewater. The third bottle served as an uninoculated control.

5 Incubation

One set of serum bottles was incubated at 37°C. The other set was incubated at 50°C.

6 Subsampling

Samples from the incubation bottles were collected at three and four-day intervals using a needle and a syringe flushed with N_2 gas as a measure to prevent sample exposure to oxygen. The samples were stored in microcentrifuge tubes at -20°C.

7 Monitoring Growth

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.



3 Medium Preparation: Selective for Fermentative Bacteria

Separately, anaerobic Tryptic Soy Broth (TSB) was prepared. The media bottles were sealed with a blue butyl rubber stopper and crimp. The headspace was then exchanged with N_2/CO_2 gas. The medium was autoclaved, and the headspace was exchanged again with N_2/CO_2 .

4 Inoculation

A set of three serum bottles with 40 mL of TSB was prepared for each incubation temperature. Two of the three bottles were inoculated with 10 mL of pasteurized wastewater. The third bottle served as an uninoculated control.

5 Incubation

One set of serum bottles was incubated at 37°C. The other set was incubated at 50°C.

6 Subsampling

Samples from the incubation bottles were collected at three and four-day intervals using a needle and a syringe flushed with N_2 gas as a measure to prevent sample exposure to oxygen. The samples were stored in microcentrifuge tubes at -20°C.

7 Monitoring Growth

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

8 Results

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

9 Conclusions

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

10 Future Work

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

11 Acknowledgements

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

12 References

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

13 Appendix

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

14 Glossary

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

15 Bibliography

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

16 Index

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

17 About the Authors

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

18 Contact Information

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

19 Disclaimer

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

20 Acknowledgements

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

21 References

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

22 Appendix

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

23 Glossary

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

24 Bibliography

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

25 Index

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

26 About the Authors

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

27 Contact Information

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

28 Disclaimer

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

29 Acknowledgements

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

30 References

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

31 Appendix

Using a UV/VIS spectrophotometer set at 600 nm, the optical density of the subsamples was measured to determine microbial growth. After measuring at 28 days of subsamples, the data was plotted against time.

Results

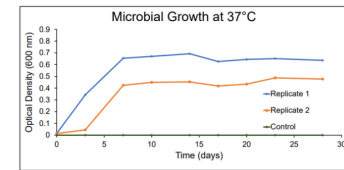


Fig. 1: Increase in optical density found in wastewater amended with anaerobic TSB medium and incubated 37°C for 28 days.

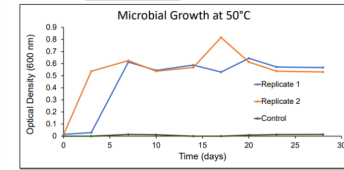
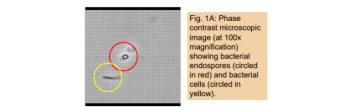


Fig. 2: Increase in optical density found in wastewater amended with anaerobic TSB medium and incubated 50°C for 28 days.

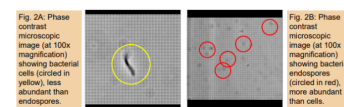


Fig. 2A: Phase contrast microscopic image (at 100x magnification) showing bacterial endospores (circled in red), less abundant than cells.



Fig. 2B: Phase contrast microscopic image (at 100x magnification) showing bacterial endospores (circled in red), more abundant than cells.

SBOE 2023 Undergraduate Intern - Report for ISU's Office for Research

Project: Investigation of spore-forming anaerobic bacteria in untreated wastewater samples from Southeastern Idaho

Faculty Lead & Mentor: Dr. Julia Martin and Dr. Anirban Chakraborty

Student Name: Douglas B. Madlock

Date: 11/15/2023

1. What did you learn from your internship experience?

Proper laboratory procedures such as extensive documentation of process and results.

2. How did this research experience benefit you?

Dr. Chakraborty's mentorship has given me the confidence to continue in a field that I found fascinating but was not sure I was bright enough to pursue. This experience has helped with my self-confidence.

3. How has this research experience changed your future plans, if at all?

I know for certain that I want to be in a field that values this type of research, such as ecology.

Investigating Anaerobic Endospore-Forming-Bacteria Within the Combined Influent Waste Streams of the Pocatello and Chubbuck Municipalities.

Douglas B. Madlock, Julia E. Martin, and Anirban Chakraborty
Department of Biological Sciences, Idaho State University, Pocatello, Idaho 83209 USA



Abstract

The ability for an endospore to lie dormant, waiting for variables such as food, temperature, pH, and/or the necessary anaerobic or aerobic conditions to become compatible with their metabolic demands, is what makes *Firmicutes*, so incredibly resilient. The focus of this study was to search for anaerobic spore-formers in the raw influent wastewater of South-eastern Idaho's Pocatello and Chubbuck city. Eight, twenty-four-hour composite samples, provided by Pocatello's Water Pollution Control (WPC) were combined and pasteurized at 60°C to kill off any microbial life that may be present. The head space within the bottle containing the pasteurized wastewater was exchanged with a mixture of N_2 and CO_2 creating an anaerobic environment. Smaller flasks containing the growth media Tryptic soy broth (TSB) were given the same anaerobic treatment then inoculated with the pasteurized waste water. For twenty-eight days the inoculated samples were incubated at 37°C and 50°C. Samples were taken regularly. Microbial growth was detected and measured using spectrophotometry.

Introduction

When exposed to suboptimal environmental factors, certain bacterium within the phylum *Firmicutes* have the ability to produce endospores. These formations develop at the end of bacilliform (rod-shaped) bacterium and contain the genetic material of the cell. Once fully formed, these spherical structures are capable of surviving for extended periods of time under extremely adverse conditions incompatible with the survival of the organism in its vegetative form. The endospore lies dormant until environmental conditions are once more conducive to its metabolic needs. This unique adaptation has given *Firmicutes*, an evolutionary advantage. The obvious advantage associated with endospore formation is the increased probability of long term survival. In addition to the preservation of microbial DNA, recent research has shown that sporulation likely plays a role in another critical function, dispersion (Chakraborty et al., 2018). On multiple occasions, endospores belonging to thermophilic *Firmicutes* (thermospores) have been found in locations too cold to support their vegetative, spore-generating form (Isaacs et al., 1994). Some academics have hypothesized that industries such as wastewater treatment facilities and anaerobic digesters may play a part in providing the thermophilic-mesophilic temperatures necessary for vegetative growth, and thus further dispersal of endospores.

Conclusions

- There were endospores present in the samples being incubated.
- Samples incubated at both temperatures showed microbial growth.
- The samples incubated at 37°C showed more robust growth than that of the 50°C samples.
- The samples incubated at 37°C generated noticeably more gas production than during first few days of fermentation of the tryptic soy broth media.

Future Work

- PCR and DNA analyses need to be done to ascertain what type of anaerobic bacteria were present in the samples.
- More media and temperature variables could be tested to discover the possible presence of other endospore forming bacterium.

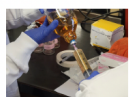
Acknowledgements

A special thanks goes out to the City of Pocatello's Water Pollution Control Department. We also acknowledge the projects final support through the FY23 SBOC-HEC Undergraduate Research Funds at Idaho State University. On a personal note, I would like to thank my wife Tara for her tremendous support.

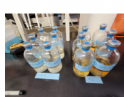
Hypothesis and Questions

We hypothesized that there would be endospores present within the wastewater samples. The questions we had related to what species of *Firmicutes* they would be and what temperature range they would prefer.

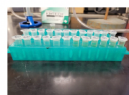
Materials and Methods



Media and preparation.



Gas exchange and anoxic preparation.



Subsampling



Subsampling setup



Preservation of samples in cold storage.



References

Chakraborty, A., Eliehan, E., U. C., Giers, D., Brooks, J. M., Bennett, B. B., & Hubert, C. R. J. (2018). Thermophilic endospores associated with migrated thermogenic hydrocarbons in deep Gulf of Mexico marine sediments. *The ISME Journal*, 12(8), 1950-1960. <https://doi.org/10.1038/s41380-018-0135-2>

Isaacs, M. F., Bak, F., & J. J. (1994). Thermophilic sulfate-reducing bacteria in old marine sediment. *FEMS Microbiology Ecology*, 14(1), 1-8. <https://doi.org/10.1111/j.1574-6941.1994.tb00984.x>

Results

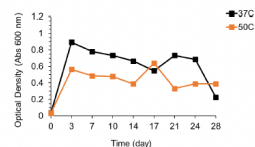


Fig. 1. Microbial growth chart showing 37°C and 50°C sampling over time.

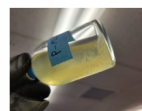
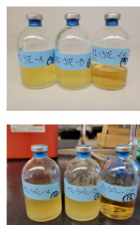


Fig. 2 Microbial growth/turbidity in incubated sample bottles.

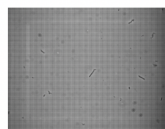


Fig. 3 endospores and bacteria at 37°C (left)

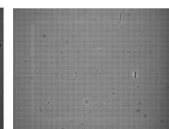


Fig. 4 endospores and bacteria at 50°C (right)

Part 3 – Report of Expenditures

Index for Expenditures: ABIO08

The three undergraduate internships occurred from November 01, 2022, to May 31, 2023 and the interns were compensated with hourly wages (\$15.00/hour). The URIs worked according to a pre-set schedule of a maximum of 10 hours per week per intern in order for the wage expenditures to be dispersed evenly throughout the project period and for all three URIs to receive equal pay. Aside from the funds to support the URIs, a small portion of the funds was used to purchase a DNA extraction kit and PCR reagents for the molecular assays.

Original Budget:

1. Wages + Fringe (3.7%) = \$7300
2. Materials and Supplies = \$700

Total = \$8000

Actual Expenditures:

1. Wages + Fringe = \$7192.30
2. Materials and Supplies = \$700

Total = \$7892.30

Student Report

By

Abigail Card

For our undergraduate research project, my research partner Kailey Pease and I conducted a literature review of the different types of treatment research on stone tools, developed a project plan, cut and prepped the chert samples, tested for surface roughness and hardness changes, and presented our findings at the ISU Undergraduate Research Symposium. I also independently presented our research at the 2023 Idaho Conference on Undergraduate Research as one of the undergraduate lightning speakers. Overall, I feel like I have learned a significant amount from this experience. It has truly shaped my undergraduate experience as a whole. I was able to gain a better understanding of the more technical and methodological aspects of archaeological research in a laboratory setting. Sometimes, things just do not work out the way that you plan them to. Extenuating circumstances can prevent certain testing or data collection methods from happening. I feel that this experience has been a wonderful introduction to the type of work that I will be doing for my University Honors Program thesis research as well as for future research in my masters program. I was already considering pursuing a graduate degree, but this opportunity to experience the reality of researching is what truly convinced me to move forward with the idea. I deeply appreciate the opportunity to participate in both the ISU Undergraduate Research Symposium and the 2023 Idaho Conference on Undergraduate Research. They gave me the ability to network with and present to other members of our field. It has been a privilege to work with the anthropology faculty here at ISU. I would like to thank Dr. Charles Speer and Dr. John Dudgeon for their mentorship. I would also like to thank Kailey Pease for her willingness to put in the hard work and time that was necessary for this project. I am thankful for this experience and I hope that the anthropology department will continue to receive more grants in the future to provide other undergraduate students with this opportunity during their time at Idaho State University.

Student Report

By

Kailey Pease

For this undergraduate research project, myself and my classmate Abby Card conducted research on water treating chert samples within an Archaeological context. Throughout this research project, we conducted a literature review, prepared chert samples, performed several tests for comparing surface roughness and hardness of the chert when dry or wet, and presented the results at the spring 2023 ISU Undergraduate Research Symposium. Overall, this project was very interesting and beneficial to my education and experience at ISU. While my education is focused on forensic anthropology rather than archaeology, this project still allowed me to learn important research methods, be challenged, and to collaborate with others. This project was also very beneficial in regards to another research project I presented in the summer of 2023 at the Idaho National Laboratory's Intern Poster Session during my archaeology internship with the company. Abby and I's project has shown me how interesting research can be and helped me realize that I want research to be an important aspect of my future career in anthropology. I would like to express appreciation to several people who have been very helpful in the success of our project. This project would not have been possible to complete without the help of our supervisors Dr. Speer and Dr. Dudgeon, CAMAS research assistant Rebecca Hazard, and the ISU Anthropology Department. I would especially like to express appreciation for my research partner Abby Card who was very hardworking and helpful to me throughout this project. Overall, I am so thankful to have had the opportunity to conduct this research project and look forward to the rest of my ISU education and future career in Anthropology.



Did Ancient People Soak Rocks in Water to Make Better Stone Tools?

Abigail Card & Kailey Pease, Department of Anthropology, Idaho State University-Pocatello

Introduction

Chert is a cryptocrystalline silicate that was commonly used in the past for making stone tools. Chert is typically ideal for making stone tools (or flintknapping) because it fractures in a predictable manner, much like glass. Chert has been used for tool making for tens of thousands of years by multiple species of hominids (see Figure 1 below). Chert is variable in its color, hardness, and fracture toughness. Some cherts do not flake as well as others and that makes it difficult to thin the stone enough to make tools. It has been suggested by modern hobbyists making stone tools that soaking Edwards Plateau chert from Texas in water for one hundred forty-four hours can improve its mechanical properties. We have outlined an experiment to test this idea using:

- Leeb Rebound Hardness Test (LRHT)
 - Looking for a decrease in hardness
- Simultaneous Thermogravimetric Analysis (STA)
 - To see if any significant water is absorbed by the chert compared to the dry control specimens
- Profilometry
 - Looking for an improvement in surface roughness



Figure 1. Projectile point flint knapped by a modern-day hobbyist with Edwards Plateau chert.

Materials & Methods

We reduced a nodule of Edwards Plateau chert into 1cm thick slabs and then processed the slab into fifteen cubes roughly one cm³ in size. The cubes were cleaned with deionized water and allowed to dry under a fume hood. The cubes were then divided into one group of ten blocks for water treatment and five blocks as a control group. The water treatment group was submerged for one hundred forty-four hours. After submersion, all fifteen samples were analyzed with:

- Leeb Rebound Hardness Test (LRHT)
 - Makes an impact on the object surface to discover the material's hardness (see Figures 2 & 7).
- Profilometry
 - To accurately measure this, we had to cleave our samples into two pieces to get a fresh surface (see Figure 8).
 - Drags a diamond tipped stylus across a material's surface to quantify its roughness (see Figure 9).

Simultaneous Thermogravimetric Analysis (STA) could not be conducted because soaked chert samples could not be effectively sieved as a slurry to accommodate STA.



Figure 2. Leeb Round Hardness Test indentations on chert matrix.

Results

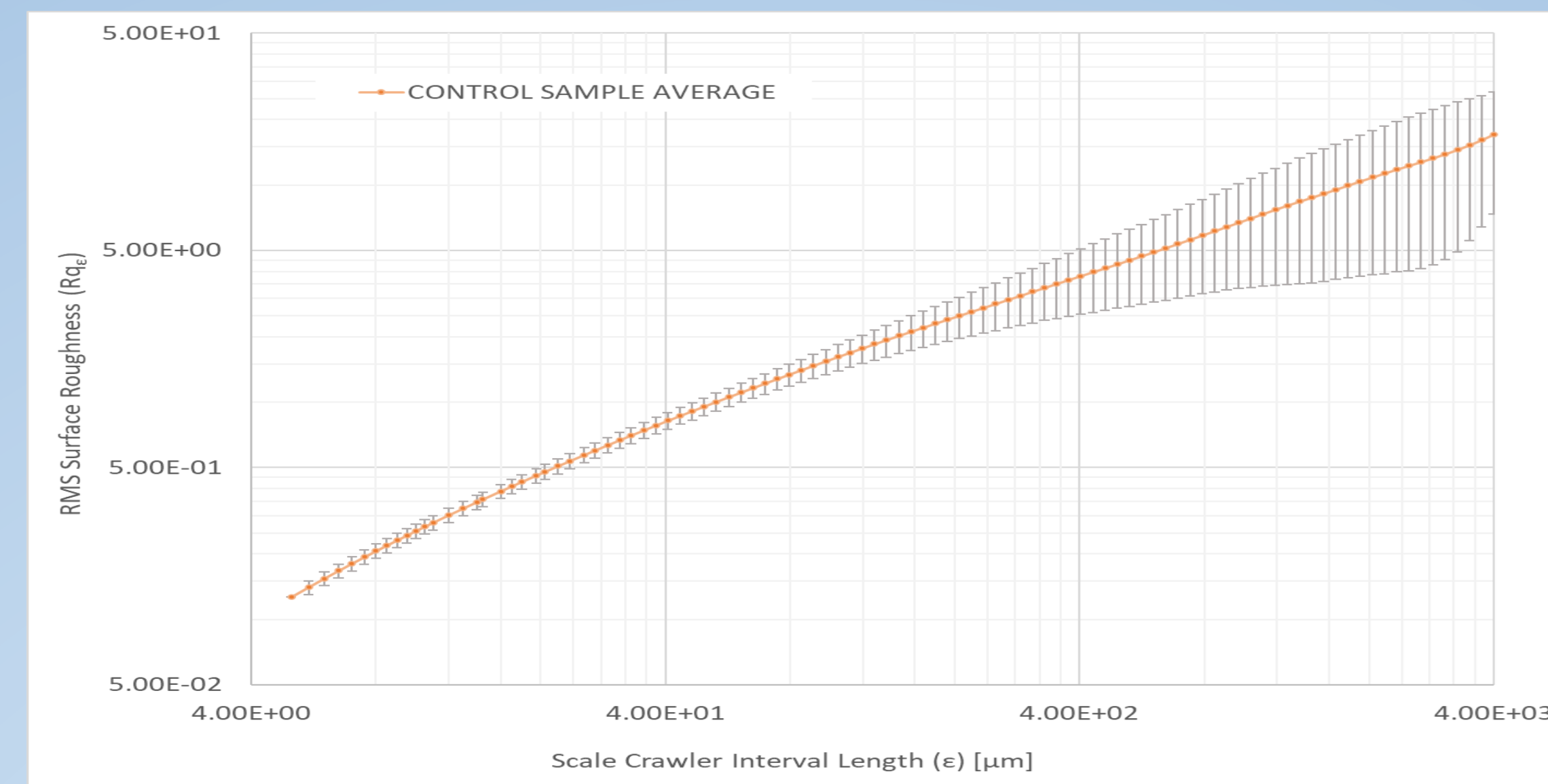


Figure 3. Surface Roughness Control Group

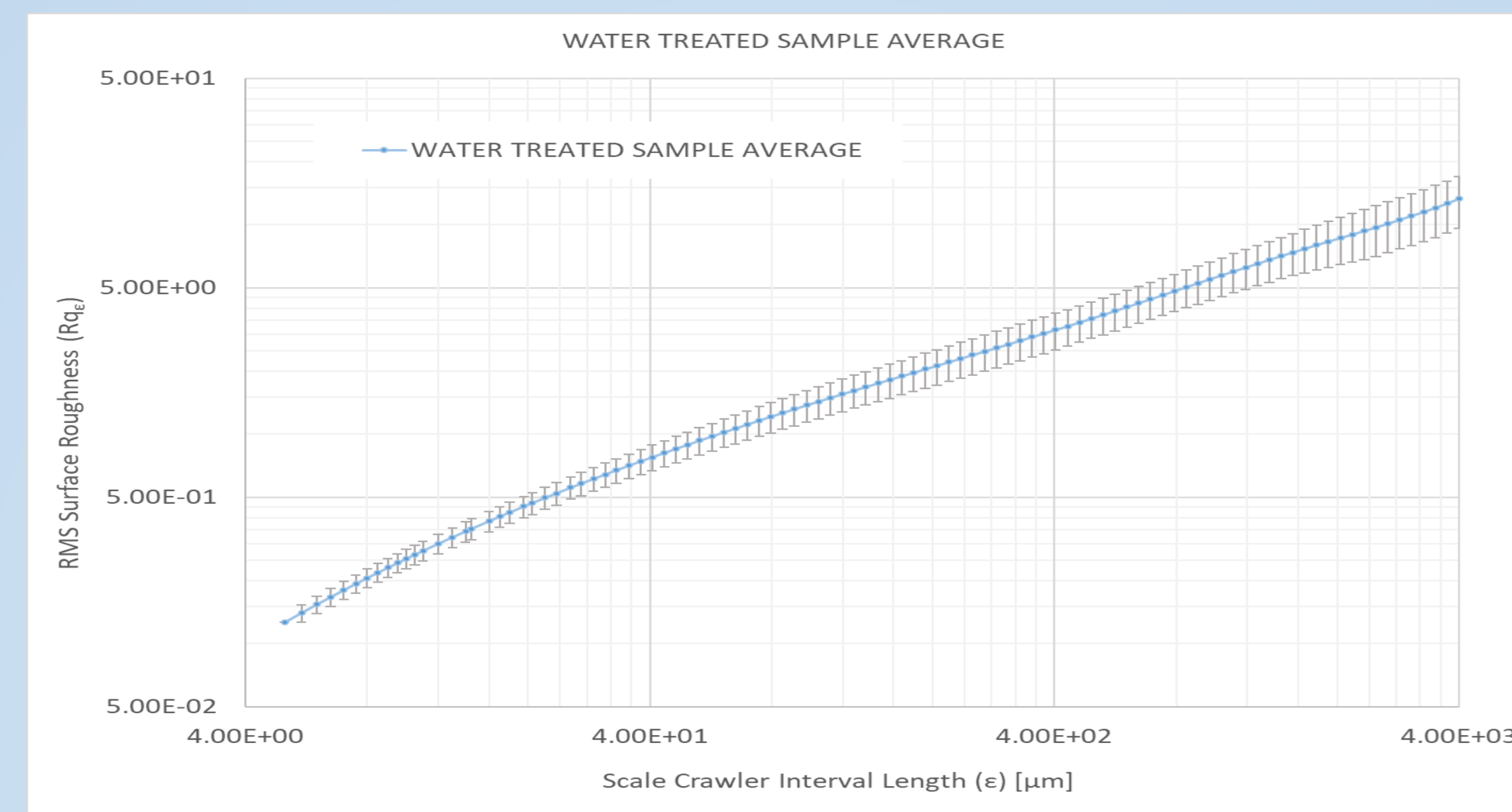


Figure 4. Surface Roughness Water Treated Samples

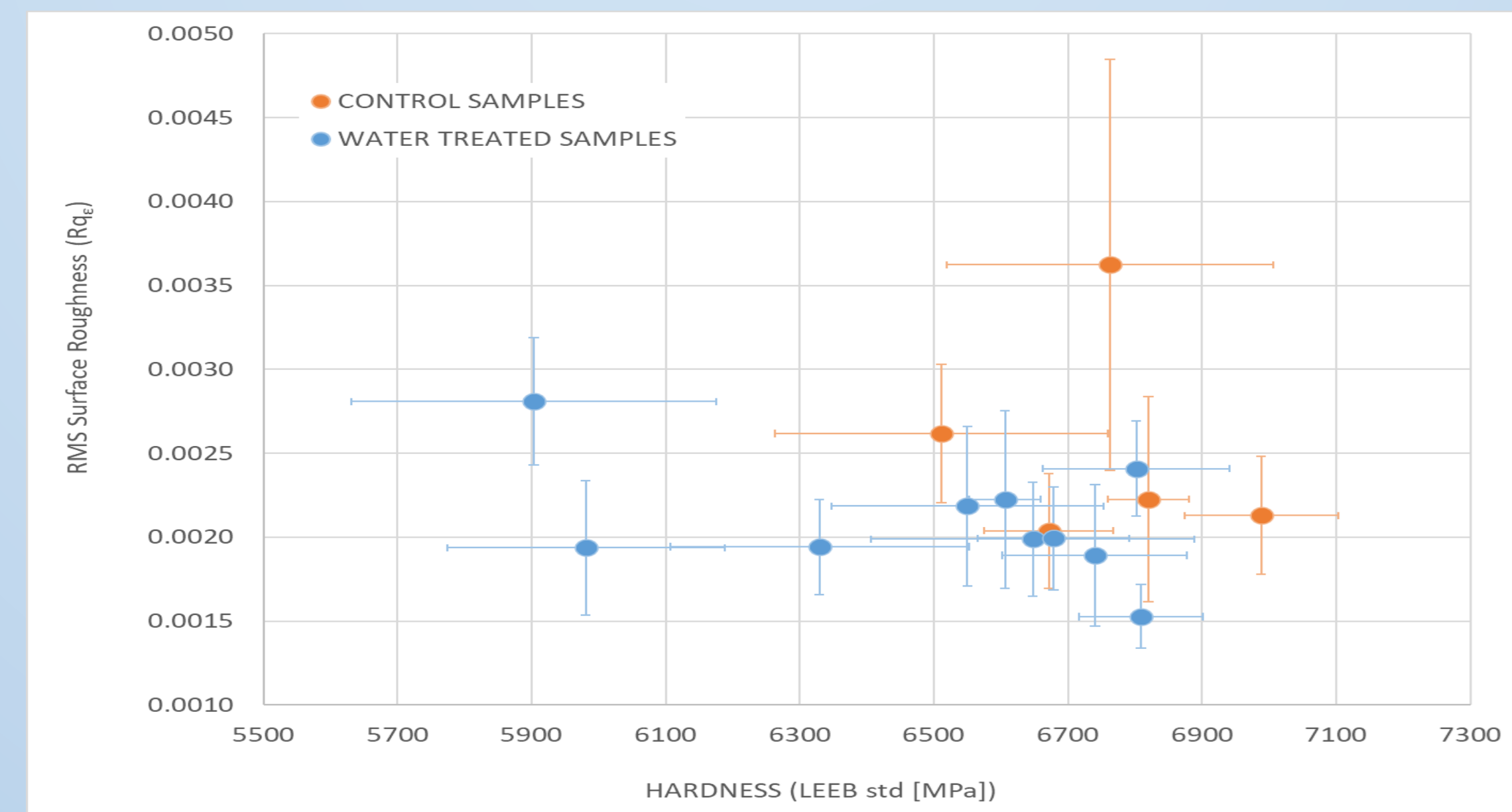


Figure 5. Surface Roughness Versus Hardness

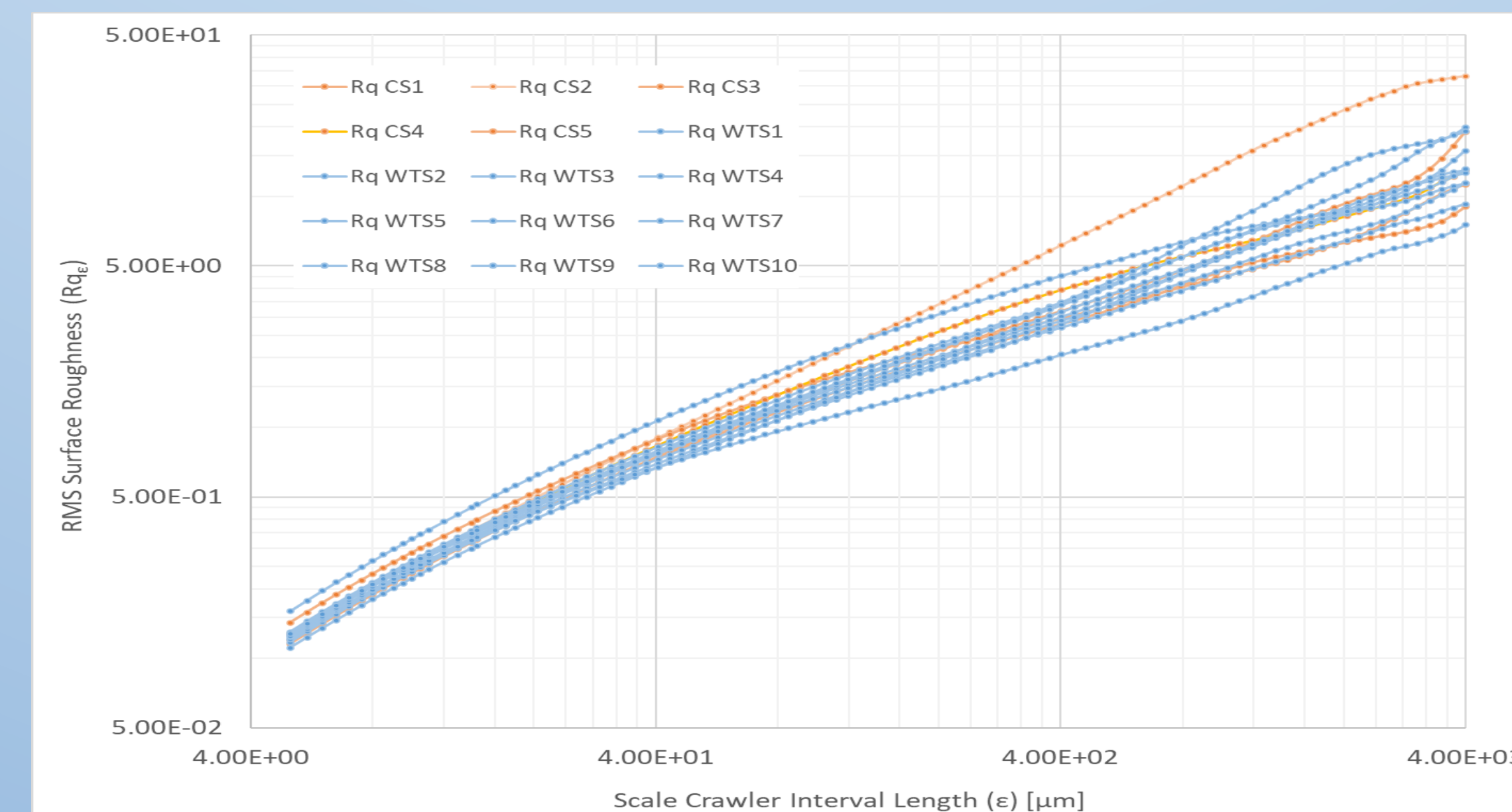


Figure 6. Surface Roughness Individual Plots



Figure 7. The LRHT apparatus being used on one of the samples.



Figure 8. This is the method in which the chert samples were cleaved for the profilometry.

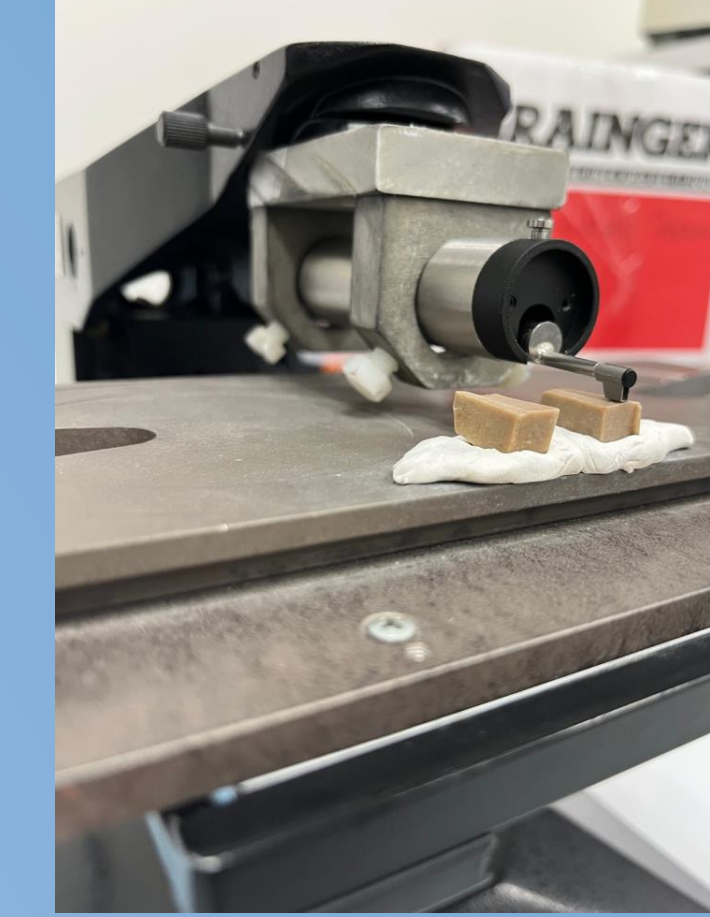


Figure 9. The profilometer scratching the cleaved surface of a sample.

Conclusion

Overall, the profilometry testing only showed a slight variation between the control and water treated samples of Edwards Plateau chert (Figures 3 & 4). The LRHT was inconclusive and did not show any significant patterning. We saw no correlation between hardness and surface roughness (Figure 5). Nonetheless, the water treated samples did exhibit a minor decrease in surface roughness of the material (Figure 6). This finding is significant to the research question, as it confirms that water treatment can affect chert and thus influence the consistency and predictability of flintknapping with this material. Though the results are minor, this data signals that further research should be conducted to see if the results are anomalous or consistently show changes. The decrease in surface roughness may be significant to the advantage of water treating chert just as it is with heat treatment of rock in the past due to the increase in predictability of flaking the surface and more uniform removal of material.

Future Research Opportunities

- Completion of Simultaneous Thermogravimetric Analysis (STA)
- Additional testing of water treated samples in three groups:
 - Control
 - Consistently soaked
 - Soaked, then dried
- Laser ablation
- Soaking samples in water for varying lengths of time
- Testing larger sized samples in greater quantities
- Alternative hardness testing

Acknowledgements

We would like to thank all of the wonderful people that we have gotten to work with during the development of our project. Specifically, we would like to thank Dr. Charles A. Speer for guiding us through this challenging process. We would also like to thank Dr. John Dudgeon and Rebecca Hazard for helping us learn how to go through the processes of preparing, researching, and testing all of the materials involved with our research. Thank you all for your continuous support.

References

- Clark, J. E. (1982). An Ethnographic Note on "Water Treatment of Flint". *Lithic Technology*, 11(1), 2–3. <https://doi.org/10.1080/01977261.1982.11760590>
- DeForest, D. S., & Lyman, R. L. (2022). Characteristics of lithic sound to assess a rock's predictability of flaking. *Lithic Technology*, 47(3), 221–230. <https://doi.org/10.1080/01977261.2022.2029284>
- Patterson, L. W., & Sollberger, J. B. (1979). Water Treatment of Flint. *Lithic Technology*, 8(3), 50–51. <https://doi.org/10.1080/01977261.1979.11754454>
- Whittaker, J. C. (2015). Fire-and-water knapping: Origins of a lithic folk tale. *Lithic Technology*, 40(1), 40–51. <https://doi.org/10.1179/2051618514y.0000000006>



Idaho State University

“In the pink”: high salt and light conditions stimulate retinoid production in *Halobacterium*

Austin Robison, Tamra Diehl, Travis Clizbe, Jeffrey Rosentreter and Caryn Evilia

Department of Chemistry, Idaho State University, 921 South 8th Ave Stop 8023, Pocatello, ID 83209

Introduction

The Great Salt Lake is almost a perfect monoculture for the archaeon *Halobacterium*. These organisms are capable of living in extreme salt (group 1 metals) and moderate trace metal concentrations. Our lab organism, *H. salinarum* ssp. *NRC-1*, is part of the GSL group and it can survive in both anaerobic (no O₂) and aerobic conditions. The organism grows heterotrophically in aerobic conditions and while under anaerobic conditions, it shows phototrophic growth (Falb et al. 2008). *H. salinarum* is a model organism for the transmembrane proteins called bacteriorhodopsin and halorhodopsin. These are transmembrane proteins that have a bound retinoid molecule which gives the organism a red/purple hue. They use energy from the sun to create a proton motive force which allows for the production of ATP. Retinoids are pigments that isomerize in sunlight, allowing protons into the cell when they swing one way or the other. *H. salinarum* is known to increase the production of retinoids via the mevalonate pathway under anaerobic conditions (Falb et al. 2008, see figure 1). For this poster, we are looking at *Halobacterium salinarum* NRC-1's ability to increase retinoid production under different growth conditions. Growth conditions included both light and dark conditions in two types of media.

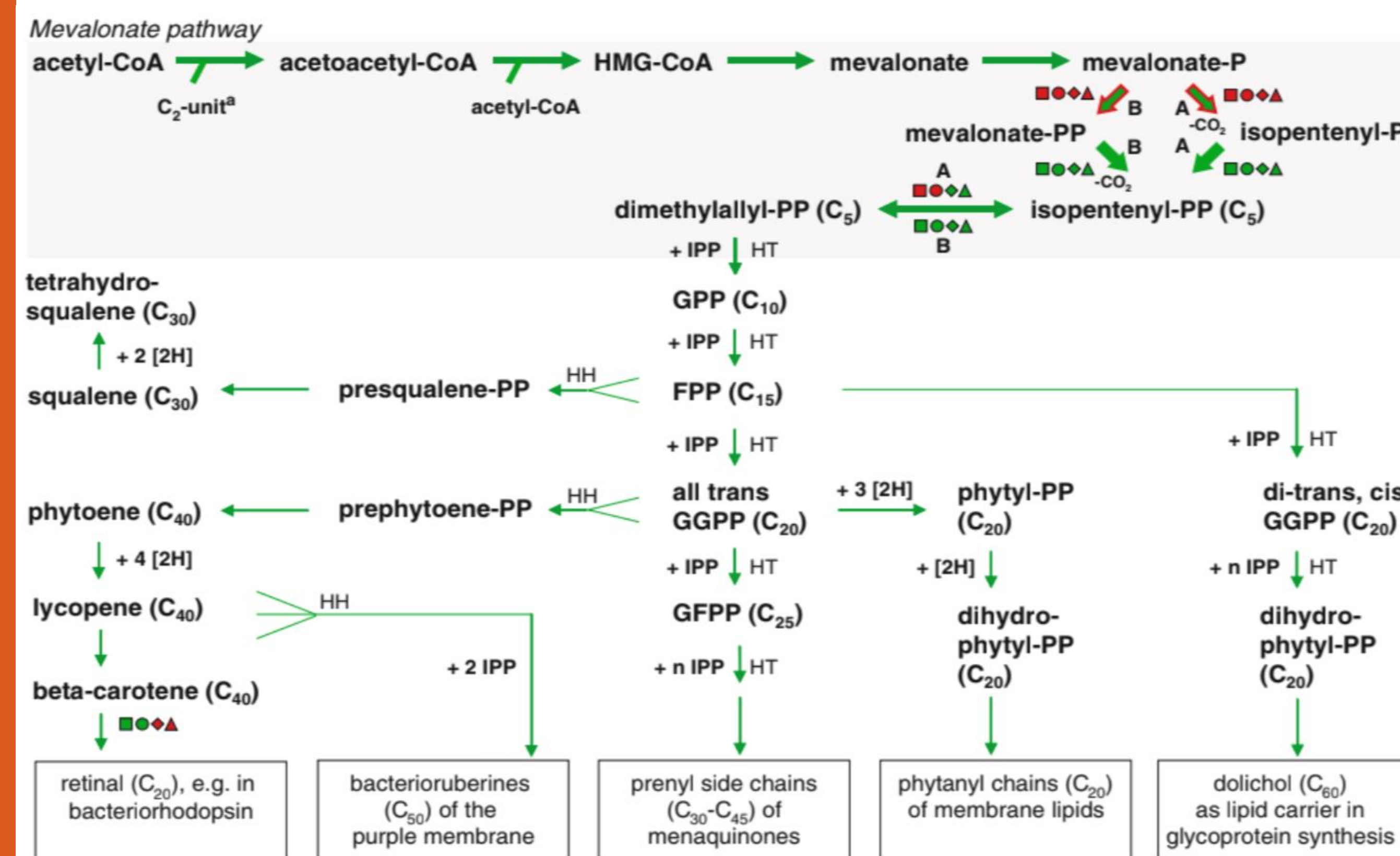


Figure 1 from reference 1. Mevalonate pathway showing how *H. salinarum* produces β -carotene and retinal for bacteriorhodopsin.

Methods

H. salinarum was grown in two different types of media. The first type of media was Complete Media+ (CM+), which includes peptone and 4.3 M NaCl, which is used to cultivate the organism in the lab normally. The second type of media, called “optimum media”, used was CM+ spiked with trace metals commonly present in the Great Salt Lake (see poster by T. Diehl, et al.). The concentration of metals added was the maximum amount that *H. salinarum* can tolerate and still grow. In each experiment, only one type of media was used, and the experimental variable tested on each type of media was the presence of sunlight or darkness. Artificial sunlight was produced by a plant growth lamp with a xenon bulb. 100 mL of media were inoculated with 2 mL of starter *H. salinarum* (grown in normal CM+). These cultures were then grown at 42 °C in sunlight, or darkness, for 8 hours a day, with their OD taken before and after the 8 hour growth period. After the 8 hour growth period, samples were grown in darkness overnight. At the end of the 5 day experiment, cells were stored in 50 mL tubes at room temperature until processed. Cells were processed for the detection of retinoids. Briefly, 5 mL of each culture was centrifuged into pellets and washed with a basal salt solution to remove excess liquid media. The cells were then resuspended in 50 μ L of water before 100 μ L of acetone was added. This lysed the cells and allowed the retinoids to solubilize into the acetone solution, leaving cell material behind. The acetone solubilized materials were diluted and the absorbance spectrum (300 -700 nm) was measured on a Genesys 10S UV-Vis Spectrophotometer and compared to a known retinoid, β -carotene.

Results

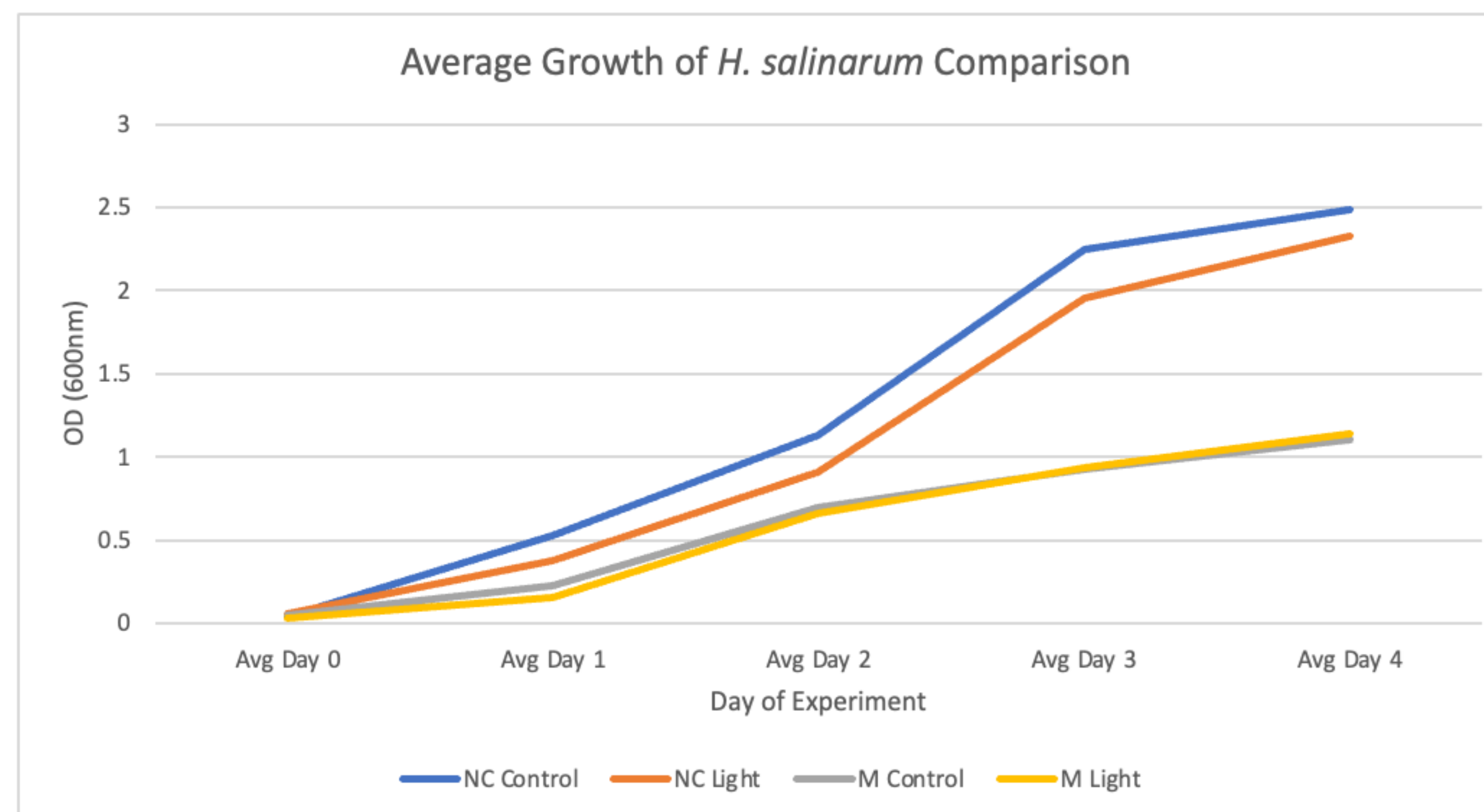


Figure 2. OD of samples taken with UV-Vis spectrophotometer set at 600 nm. Average was for each type of sample over the 5 day experiment. OD value used was after the 8 hour day light/dark experiment. This shows a significant difference between normal CM+ and maximum CM+, but no difference between light/dark conditions across media types.

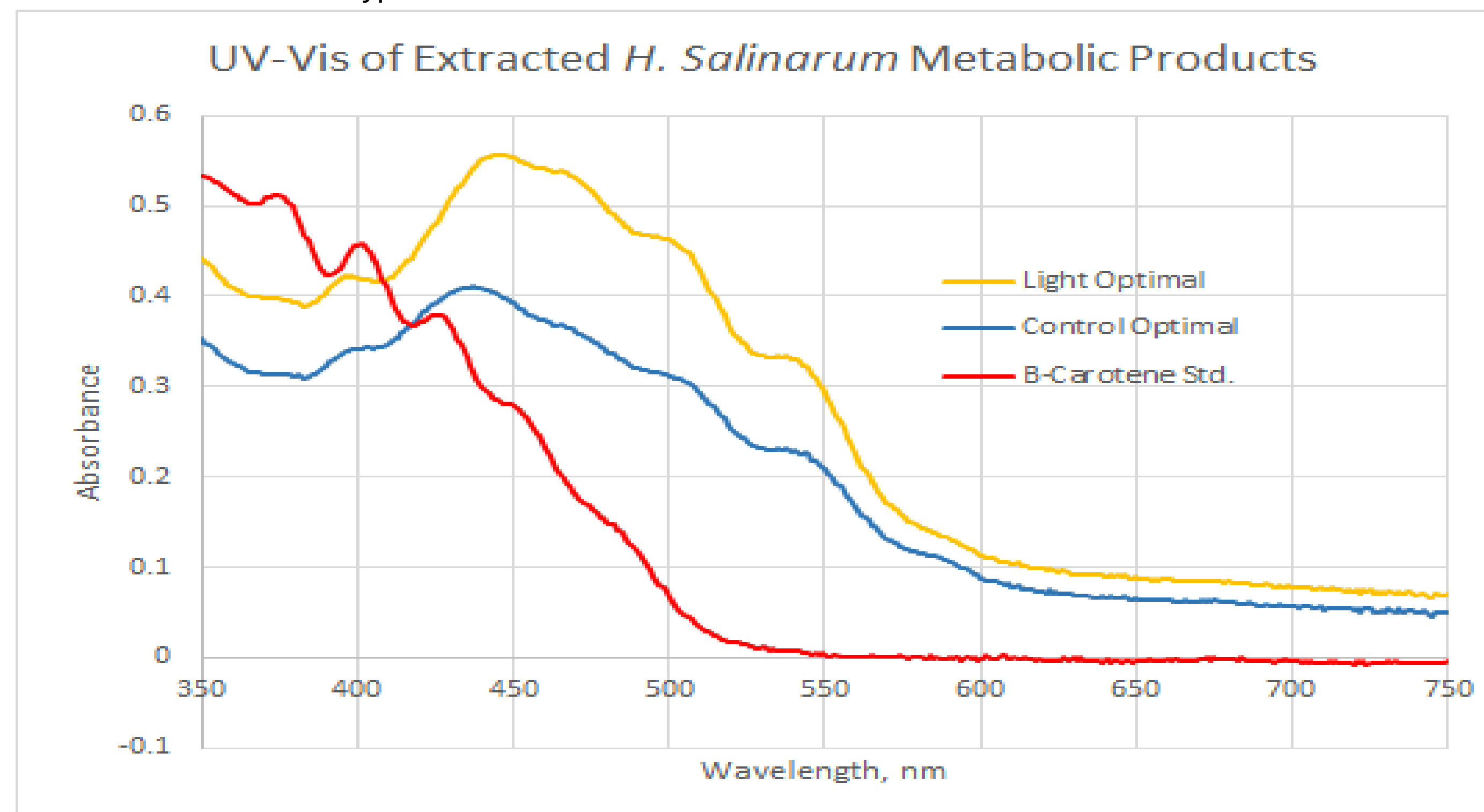


Figure 3. Initial UV-Vis of the extracted metabolic products from the halobacterium compared to a β -carotene standard in acetone. The λ_{max} for the β -carotene standard was significantly lower than the halobacterium's products. This may suggest there are other retinoids causing the phenotypic change. Traditionally, β -carotene has a λ_{max} around 453 nm, and other carotenoids have absorbance maxes around 450 nm. The difference in β -carotene's λ_{max} values may be investigated further.

Discussion/ Future Work

In aerobic conditions there was no noticeable difference in phenotype between cultures grown in light and dark conditions between the two types of media. The initial hypothesis for this experiment was made due to notable phenotypic characteristics between cultures grown in light and dark conditions. We can draw the conclusion that the lids used on samples in early experiments were creating enough of a seal for the samples to be growing in anaerobic conditions. There is a significant difference in phenotype between cultures grown in Maximum CM+ and normal CM+. Future work with the retinoid assays may help elucidate the cause of this difference in phenotype. Possible causes are increased production of retinoids, insufficient gas vesicle inflation/deflation, or some unknown factor. More future work with testing cultures in salt concentrations found within the Great Salt Lake may give us a different phenotypic and metabolic shift in the organism.

Results: Cultures grown in normal CM+ in both light and dark conditions had no visible phenotypic difference. This result was mirrored for cultures grown in maximum media with no noticeable phenotypic difference between cultures. These results showed that the presence of sunlight did not have a larger impact on retinoid production and it is likely more influenced by oxygen availability. However, there were notable differences between cultures grown in normal CM+ and maximum media. The first was that spent media from cultures grown in maximum media was a much darker orange color compared to that of cultures grown in normal CM+. The second was that cells grown in normal CM+ were able to form a pink pellicle at the top of the spent media when stored. Cells grown in maximum media would sink to the bottom of the spent media when stored and had a darker purple color. Processed cells resulted in a red-orange solution, similar to common retinoids (Figure 5). Cells grown under sunlight conditions resulted in a λ_{max} of 445 nm, while dark conditions resulted in a λ_{max} of 437 nm. β -carotene was measured to have a λ_{max} between 350-400 nm.

Figure 4. Comparison of phenotypes between all four types of samples, control CM+, light CM+, control maximum CM+, and light maximum CM+. A) Normal CM+ cultures grown in light and dark conditions. B) Maximum CM+ cultures grown in light and dark conditions. C) Control normal CM+ culture vs. Control maximum CM+ culture. D) Light normal CM+ vs. Light maximum CM+ culture. This shows significant phenotypic differences between maximum CM+ and normal CM+, but not between light/dark conditions.

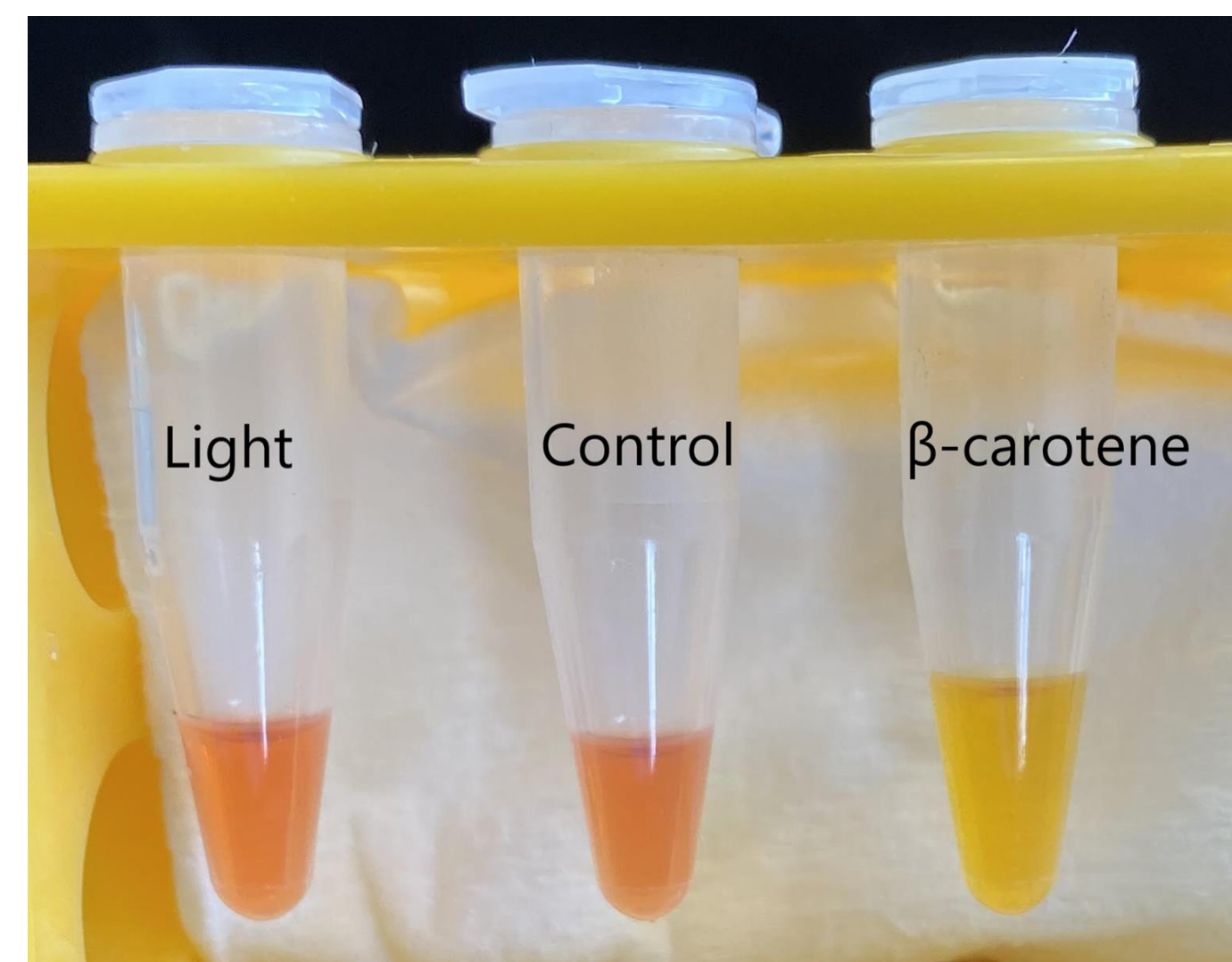


Figure 5. Solubilized retinoids in acetone from halobacterium grown in light or dark conditions compared to β -carotene. There is a significant difference in the β -carotene's color compared to the halo-extracted solutions. This indicates there is little β -carotene, or other retinoids are causing a change in phenotype.

Acknowledgments

- This project was supported by a 2022-2023 STEM Undergraduate Research Grant from the Higher Education Research Council.
- Idaho State University Chemistry Department

References

- Falb, M., Muller, K., Konigsmäier, L., Oberwinkler, T., Horn, P., Gronau, S., Gonzalez, O., Pfeiffer, F., Bornberg-Bauer, E., Oesterhelt, D. “Metabolism of halophilic archaea.” *Extremophiles*. 12:177-196. 2008. DOI 10.1007/s00792-008-0138-x

HERC report

A final lab/project award report will be due to ROC by July 15, 2023. This report will have three parts:

1. A description of the activities undertaken, how the lab/project benefited from the funds, how the research goals of the lab/project were furthered. Include your thoughts on the mentoring portion of the project. Did you complete the activities described in your proposal? What might you do differently next time?
2. Student reports as described below.
3. A report of expenditures.

Funds must be spent by June 1, 2023, with no extensions granted.

B. Responsibilities of the Student Participants

Students who receive these research funds are expected to participate in a poster presentation. Acceptable presentation opportunities include the ISU Undergraduate Research Symposium, the Idaho Conference on Undergraduate Research, or a discipline-specific symposium or conference. Virtual conferences are acceptable presentation forums.

Students will provide their lab/project lead researcher a report describing what they learned, how the research experience benefitted them, and whether the experience has changed their future plans. This student report should be submitted as an electronic file (jpg or pdf) and will include a copy of their poster.

1A. A description of the activities undertaken, how the lab/project benefited from the funds, how the research goals of the lab/project were furthered.

The purpose behind getting these funds was to support two undergraduates during their training in microbiological/ biochemistry methods in order to make progress on our lab's project to characterize the microbial population of the Great Salt Lake. To this end, both Austin and Tamra made great progress. They used previous data from our lab to design growth media for our model lab organism, *Halobacterium salinarum*, to determine optimal and extreme growth conditions. These experiments were designed around training them in microbiological methods, so that we could work with environmental samples from the Great Salt Lake. The specific techniques that were learned (in addition to general lab procedures and protocols in microbiology and

biochemistry) were microbial culturing of halophiles, how to collect environmental samples, and creating filters for microbial analysis. Outside the lab procedures, we have also talked about how much data is needed for publication, how scientists and how we will write a manuscript. Before the end of our funding, we generated an outline for our manuscript. Over the course of this summer, we (Tamra, Austin and I) will be writing a manuscript for publication on their data that they collected on our media project. Our goal is to submit it for publication by September 2023

In this way, my lab and this project greatly benefited from having the financial support for Tamra and Austin. Because neither of them had to seek employment elsewhere, they were able to spend more time in the lab which allowed them to keep trying different conditions to determine the maximum conditions our lab organism can tolerate. This furthered the goals of this project which we have been able to disseminate by giving scientific presentations and posters, as well as by writing up our results for publication in a scientific journal.

1B. Include your thoughts on the mentoring portion of the project. Did you complete the activities described in your proposal? What might you do differently next time?

We did all of the activities in our proposal. I met with Tamra and Austin every week- often more than once per week – to check in with them. This was very helpful because they were getting results that were unexpected. This required constant tweaking of the experimental conditions and redoing the experiments. Both Tamra and Austin did an amazing job adapting to the constant changes. Most students don't like to be told that they must do their experiments over and over again. By repeating experiments, we were assured that the scientific method was being followed and the results we generate were real. I know Tamra and Austin understood this and we discussed this during our meetings. The good news is that their hard work is paying off as we have plenty of data for a manuscript, which they are helping me to write.

Austin and Tamra worked very well as a team. They talked to each other regularly and switched off duties as their schedules were different. This allowed them to keep the experiments going and provided additional controls for our experiments. Because they took turns doing the culturing and media preparations, we could make sure that the results weren't because of just one person. I am also proud to say that while Tamra and Austin didn't always agree in the interpretation of our results, and this led to a few in-lab debates – they were good debates. In the end, they were both right. They came up with tests of their different interpretations and it satisfied both of their concerns. I have had students debate each other before, but they were on different projects so only one would be able to test their hypothesis. This, for me, was much more satisfying, pedagogically, and I think Austin and Tamra learned a lot in the process.

While this project progressed very well and I feel Austin and Tamra got a lot out of it, there are things I would do differently the next time around. Having a supported team of two undergraduates was a good way to go, but personalities sometimes clash. In general Austin and Tamra got along well, but they had different outlooks that seemed to cause them some strife. For example, Tamra didn't see the need to hang around the lab after experiments were done or in progress, but Austin did. In these afterhours hangouts, he was troubleshooting, and she had left.

After some time, we all talked and this led to some solutions: Tamra would touch base with Austin, even after all was complete for the day. They also talked by the Slack app and by texting, so our communication issue was worked out. The next time around, I think we should discuss some of these issues, especially communication, at the beginning of the project, rather than towards the end.

2. Student reports

HERC 2022-2023 final student reports - Evilia

"Students will provide their lab/project lead researcher a report describing what they learned, how the research experience benefitted them, and whether the experience has changed their future plans."

Tamra Diehl – HERC report

My research project was a fun and informative experience, and I would highly recommend other students to engage in research. This experience has allowed me to improve my ability to communicate complex concepts and information to others as well as apply critical thinking and problem solving to diverse situations. For example, while having a group meeting in lab, I was able to suggest making a minimal media to grow halophiles, to see how it responds to the addition of bicarbonate to the growth media. Even though the difference ended up being minimal I was still able to learn from the experience of hypothesizing and developing testing procedures.

This experience also provided me with multiple tangible benefits in several different areas. First, I gained invaluable experience in the process of research. My scientific techniques and methods improved due to the varied demands of my project, allowing me to practice and learn outside of the classroom. For example, my pipetting skills have greatly improved, and I am comfortable running a variety of instruments, including spectrophotometers. Additionally, my communication and collaboration skills were improved through opportunities to assist and train coworkers with different aspects of their experiments. While my research experience did not change my plans for the future, it did solidify my goals to attend graduate school to study biochemistry.

In terms of the science and my project, we were able to learn about many things about our halophiles. First, they are extremely tolerant to several different metals. For example, halobacteria can survive and grow in three molar concentration of lithium, which is 100,000 times the concentration of seawater. This was interesting because in the Great Salt Lake, the lithium concentration was only 57.6 $\mu\text{g/mL}$ or 8.30 millimolar which is significantly lower. We were able to see how well halobacteria can live in such extreme environments by testing a variety of different metals. The other most notable thing we learned about halobacteria was that it can have a phenotypic change due to the addition of these metals and when introduced to artificial sunlight.

This research has allowed me to become a more well-rounded scientist and has given me the opportunity to study a truly fascinating organism. I really appreciate this opportunity and am grateful for the experience I have gained.

Austin Robison - HERC report

This experience taught me how important communication is while working on a project with multiple individuals. I really enjoyed being able to work as a team on separate parts of one question and be able to bring together all of our work to come up with an answer. It required effective communication between me and my lab mates to be able to have our experiments coincide with each other towards the same goal. Coordination of lab equipment was also a key to being effective as a group as well. I see this increased use of communication as a major benefit to my abilities as a researcher and am grateful that I was able to hone this skill. I also learned how important it is to look at a scientific question from every angle before drawing conclusions from your data. Being able to recognize factors that impacted your result will allow you to draw sound conclusions, which is the goal of any good researcher. My plans have not changed through this experience and I plan to continue my pursuit of education and educating others. It has increased my drive to continue learning about everything I can. This was very helpful in solidifying my plans for grad school. Through my project I have realized that I want to increase my knowledge in the field and then pursue a career in industry/academia that will allow me to help others. Whether that help takes the form of teaching or increasing understanding of the field, a masters degree will help increase my ability to do this. This funding allowed me to focus on my work without distractions and be able to increase my enjoyment in the field and support myself at the same time. Because of that I now think that I would love to do this for a career.

For the science part of my project, I learned a lot about *Halobacterium salinarum*, which is an organism commonly found in the Great Salt Lake. Halobacterium is a salt loving, metal tolerant organism that can grow with or without oxygen. This organism is a poly-extremophile, meaning that it can live in conditions far outside the conditions of mesophilic or “normal” organisms. In my project, I was looking at the effects of metal concentration and sunlight on the growth of Halobacterium. After testing many factors that influence halobacterial growth, the factor that influenced growth the most was metal concentration and not sunlight under oxygen-rich conditions. We also found that in conditions without oxygen there is a large phenotypic difference when the level of sunlight changes during growth, which had already been established in the literature. Overall, our results agreed with work previously done and furthered our understanding of growth conditions for *Halobacterium salinarum*.

3. Expenditures report

Current Year

▼

Period

Jun-2023

▼

Budget

Annual Adjusted Budget

▼

fx

Current Fiscal Year / Current Period

Chart = 9

|

Fund = 110000 ISU General Clearing

|

Orgn = 311803 CHEM Research Funds

|

Prog = 04ORO Organized Research on Campus

⚙️

📊

📈

🟢

🔄

Acct	Title	Jun-2023 YTD Actual	O/S Commitments	YTD Total Activity	Annual Adjusted Budget	Budget Available	Budget Fav/Unfav
Operating Expenses							
6204	Student Non-Work Study	7,505	0	7,505	0	-7,505	U
6310	Fringe Allocation	278	0	278	0	-278	U
	Subtotal	7,782	0	7,782	0	-7,782	0% U
	Total Expenses	7,782	0	7,782	0	-7,782	0% U
Operating Expenses							
720	Services	0	0	0	8,000	8,000	100% F
7214	Empl Conference/Training Regist...	175	0	175	0	-175	U
7231	Field/Student Trip (not research)	178	0	178	0	-178	U
7271	Freight/Shipping	10	0	10	0	-10	U
7371	Lab Supplies/Lab Equip LT \$300/i...	265	0	265	0	-265	U
	Subtotal	628	0	628	8,000	7,372	92.1% F
	Total Expenses	628	0	628	8,000	7,372	92.1% F
	Total All Expenses	8,410	0	8,410	8,000	-410	5.1% U
	Total Revenues Less Expenses and Transfers	-8,410	0	-8,410	-8,000	-410	5.1% U

1. Wages budget (\$4,940). I spent \$7,505.

Austin Robison and Tamra Diehl were paid \$7,505 over the course of this proposal (November 2022 – May 26, 2023). This amounts to 577 hours of work over 23 weeks. While I had budgeted for less time, they were making good progress, so I sacrificed some of my travel and supply budget to pay them for additional work on the project. However, due to issues with getting status reports, I overspent by more than I anticipated.

2. Total fringe budget (\$182.78). I spent \$278.

Because they worked more hours, we spent more on the fringe. We spent \$278.

3. Research travel budget (\$1,983). I spent \$353.

I had budgeted funds (\$1,798) for both students to attend the American Chemical Society meeting in Indianapolis, IN. However, neither student was able to attend this meeting. Instead, both students did posters at the ISU undergraduate symposium (April 13, 2023) and I was able to pay for Austin's virtual registration (\$175) for Brines Across the Solar System, which is a NASA sponsored meeting (in-person part was in Reno, NV on May 15-19, 2023).

Additional Research travel: ISU Van rental for collecting samples at the Great Salt Lake, UT: \$178.

Because we will need to collect environmental samples as a culmination of this project, I rented an ISU van for us to go to the Great Salt Lake. Our trip was on May 11, 2023. The van rental plus fuel was \$178.

4. Materials and supplies budget (\$700). I spent \$275.

I spent \$275 on consumables for this project. While I could have spent more, I used the bulk of these funds to support Austin and Tamra instead.

Total: \$8,410



Recreating *Halobacterium salinarum*'s Native Environment for Optimal Lab Growth

Tamra Diehl, Austin Robison, Katelynn Miller, Talia Cahoon, Jeffrey Rosentreter and Caryn M. Evilia

Department of Chemistry, Idaho State University, 921 South 8th Ave Stop 8023, Pocatello, ID 83209

Abstract

Due to the Great Salt Lake, Utah's (GSL) hypersaline environment, it is easy to assume no organism could live in its depths. The lake has high concentrations of Group 1 and 2 ions, as well as transition metals, making the GSL toxic for most forms of life. However, to the extreme halophiles that live in the lake, these are the conditions that support their life. To better understand how they survive in this hypersaline environment, *H. salinarum* (Hs), a resident of the GSL and model halophilic archaeal organism, was grown in standard media, spiked with different concentrations of metals, based on our analysis of the GSL water. Cell growth was measured daily by measuring cell density at 600 nm. The results demonstrate that Hs grows better, in general, in the media spiked with individual metals and media containing all tested metals. Furthermore, the data showed that Hs grew better in media spiked with Group 1 ions (lithium, sodium, potassium, etc.) versus media with Group 2 ions (magnesium, calcium) or transition metals. To further understand how Hs grows in its environment the cells were also subjected to growth under simulated sunlight. The results show that the sunlight increases Hs growth rate, even in the presence of high concentrations of metal ions. This new information on how Hs grows in different metals and sunlight allows for a better understanding of how these metal-rich environments impact Hs and the limits to which life itself can be pushed.

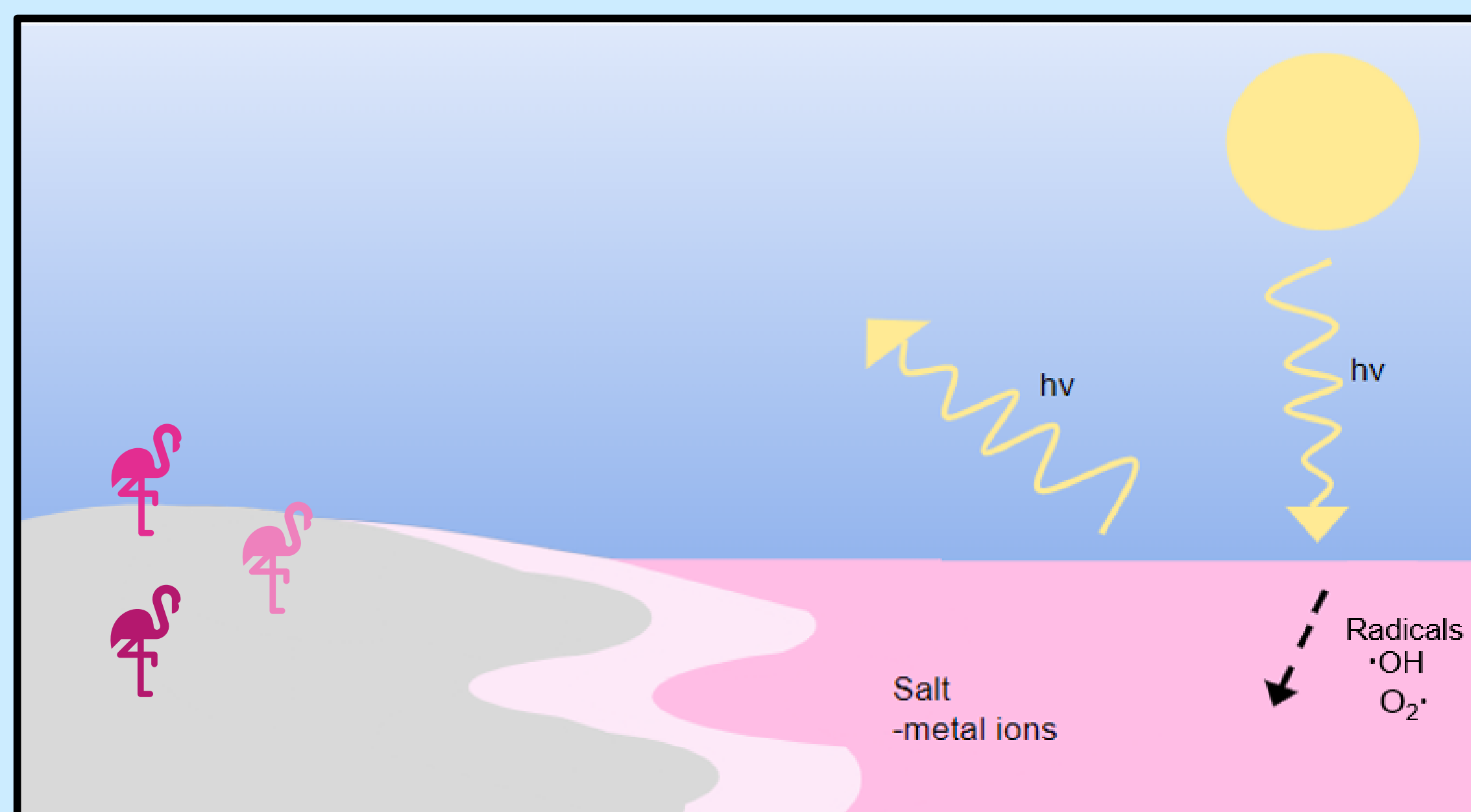


Figure 1: Depiction of the GSL and the chemistry that goes on in its waters.

Introduction

The Great Salt Lake (GSL) in Utah is a great example of an extremely saline environment that is populated by the extreme halophiles; mostly archaeal organisms that are frequently found in unusual and extreme environments. A GSL water analysis was done in our lab to evaluate the metal content of the lake. Our traditional media, CM+ (4.3 M NaCl, 81 mM MgSO₄·7H₂O, 27 mM KCl, 6.3 μM FeSO₄·7H₂O, 1.5 μM ZnSO₄·7H₂O, 2.2 μM MnSO₄, 0.040 μM CuSO₄·5H₂O), that is used to culture our lab's model organism, *Halobacterium salinarum* (Hs) has sub-micromolar concentration of metal, while the GSL water has milli- to molar concentrations of different metals. The CM+ media was developed over 40 years ago, and *Halobacterium* grows well in it¹. This media, however, does not reflect the actual saline environment these organisms live in. In this era of metagenomics and microbial ecology, more research is being done to develop new medias that use knowledge of these environments and their associated microbiome to improve in-laboratory cell growth. From past work in our lab, the GSL was found to have high concentrations of group 1 and 2 metals as well as some transition metals (figure 2). To better understand how "wild" halobacterium survives in an environment with such an abundant number of metals, we grew our laboratory strain with different metals at concentrations similar to the GSL's metal content, as well as under simulated sunlight to better replicate its environment.

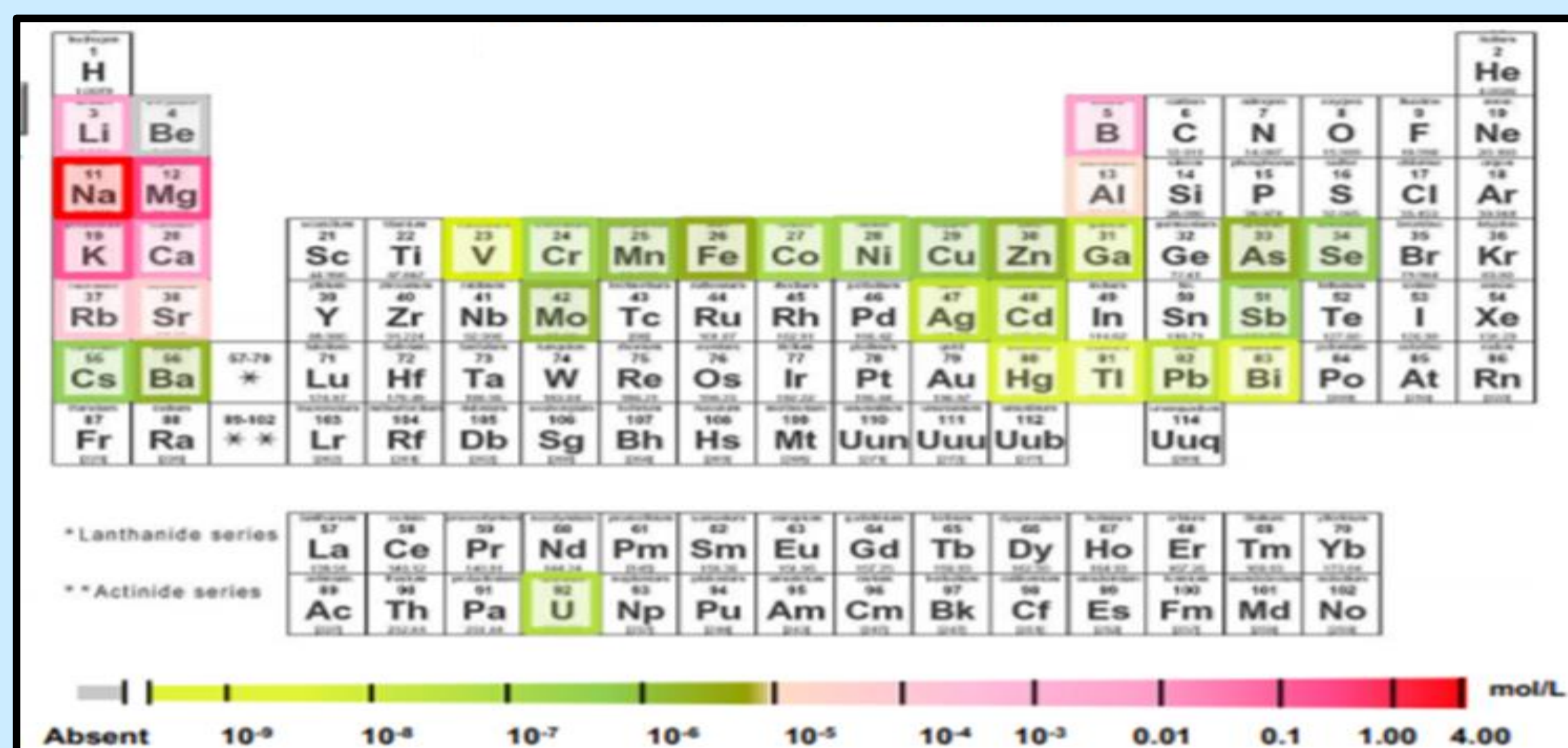


Figure 2: Metals of Great Salt Lake as determined by ICP-MS analysis of GSL water after native cells are removed. Only tested metals are highlighted.

Methods

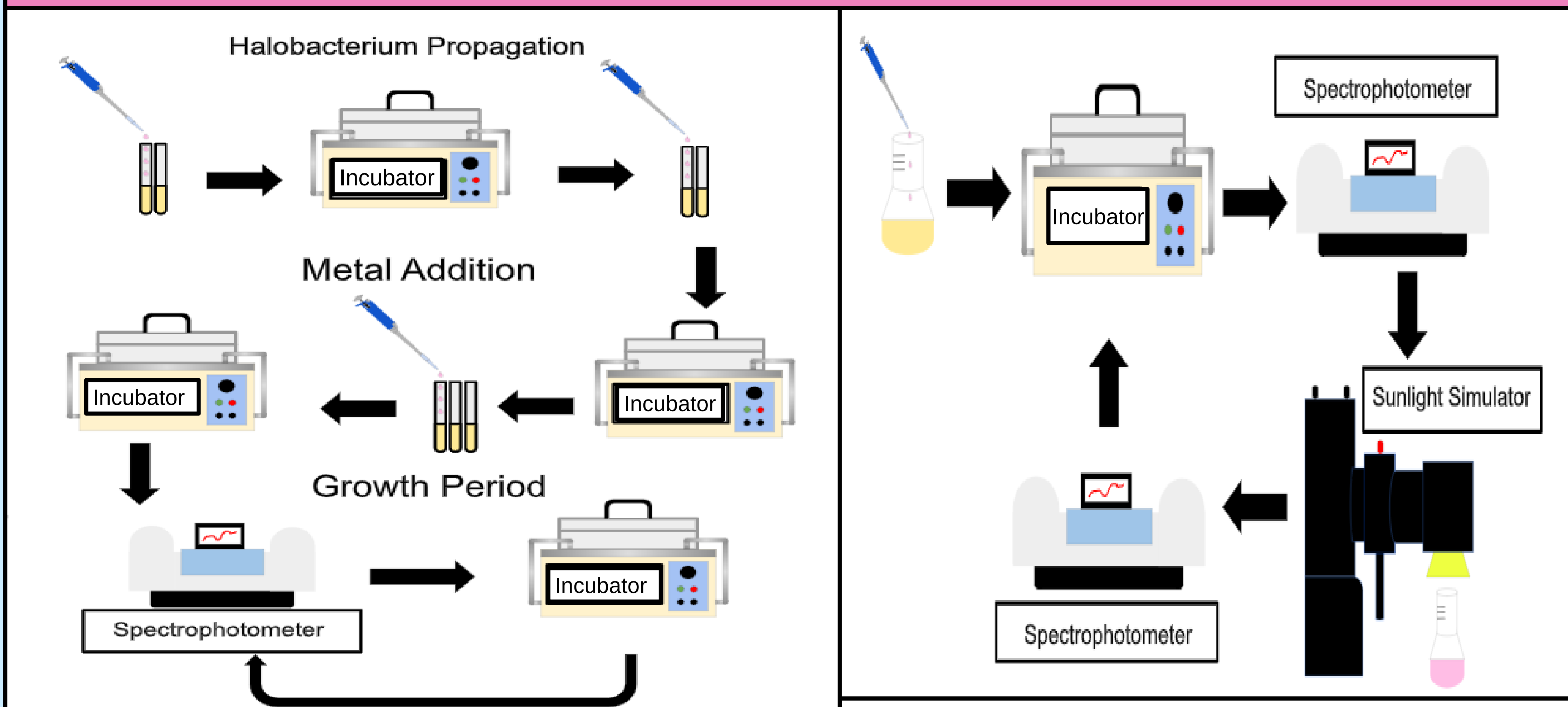


Figure 3: 100 μL of halobacterial culture was inoculated into 5 mL of CM+ Media and incubated at 42°C at 220 RPM. Cultures were grown to exponential phase. After propagation, cultures were made with the different metals at varying concentrations. All the cultures were done in triplicate. Cell density was recorded at an absorbance of 600 nm. These values were recorded, and a growth curve was generated.

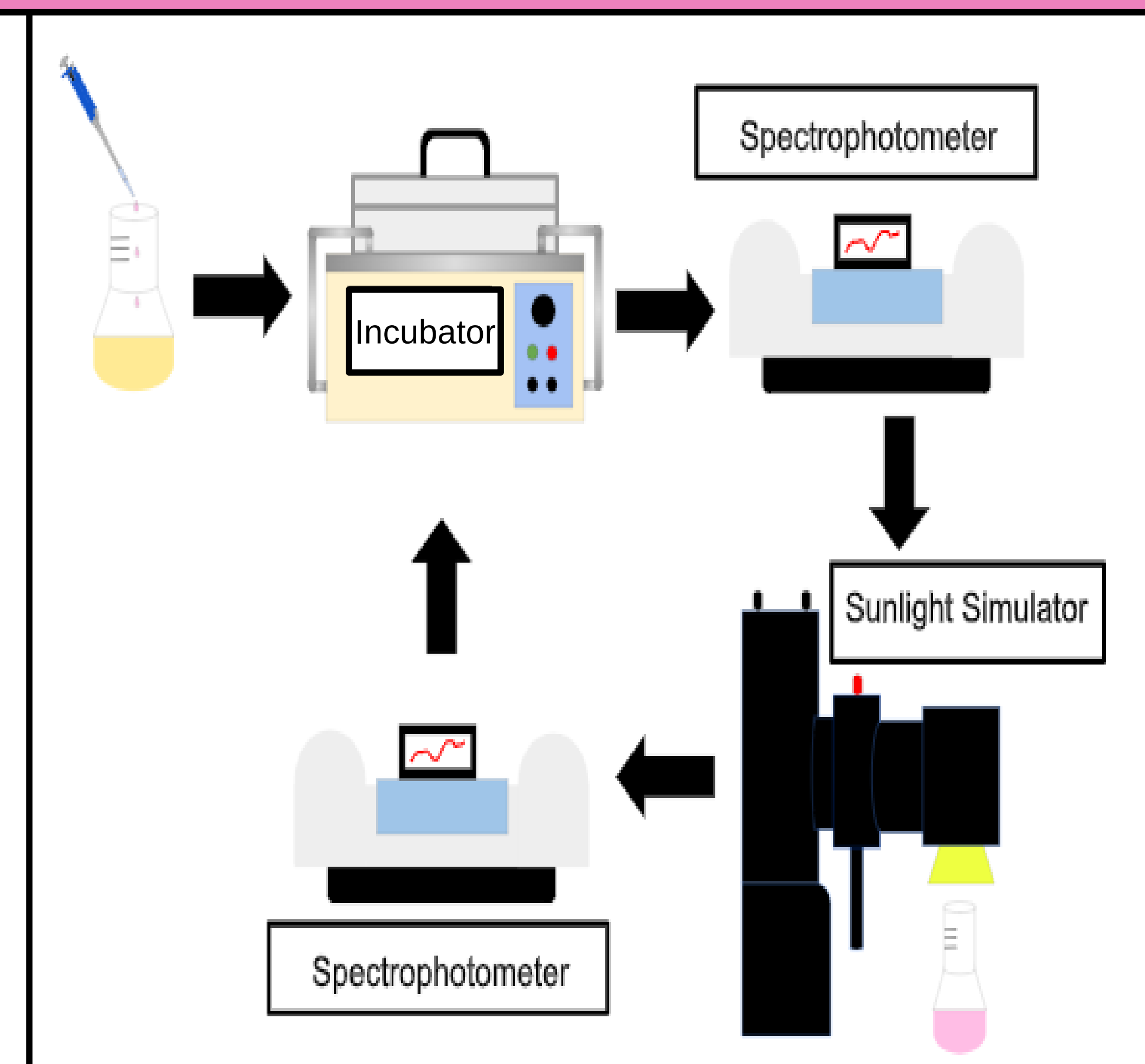


Figure 4: 2000 μL of halobacterial culture was inoculated into 100 mL CM+ or Optimal media and incubated for 4 days at 42°C at 220 RPM. For 2 hours each day the culture is incubated under artificial sunlight via a Sciencetech Inc., xenon lamp. The density is taken at an absorbance of 600 nm twice a day, before and after light treatment. From these data, a growth curve was created.

Results

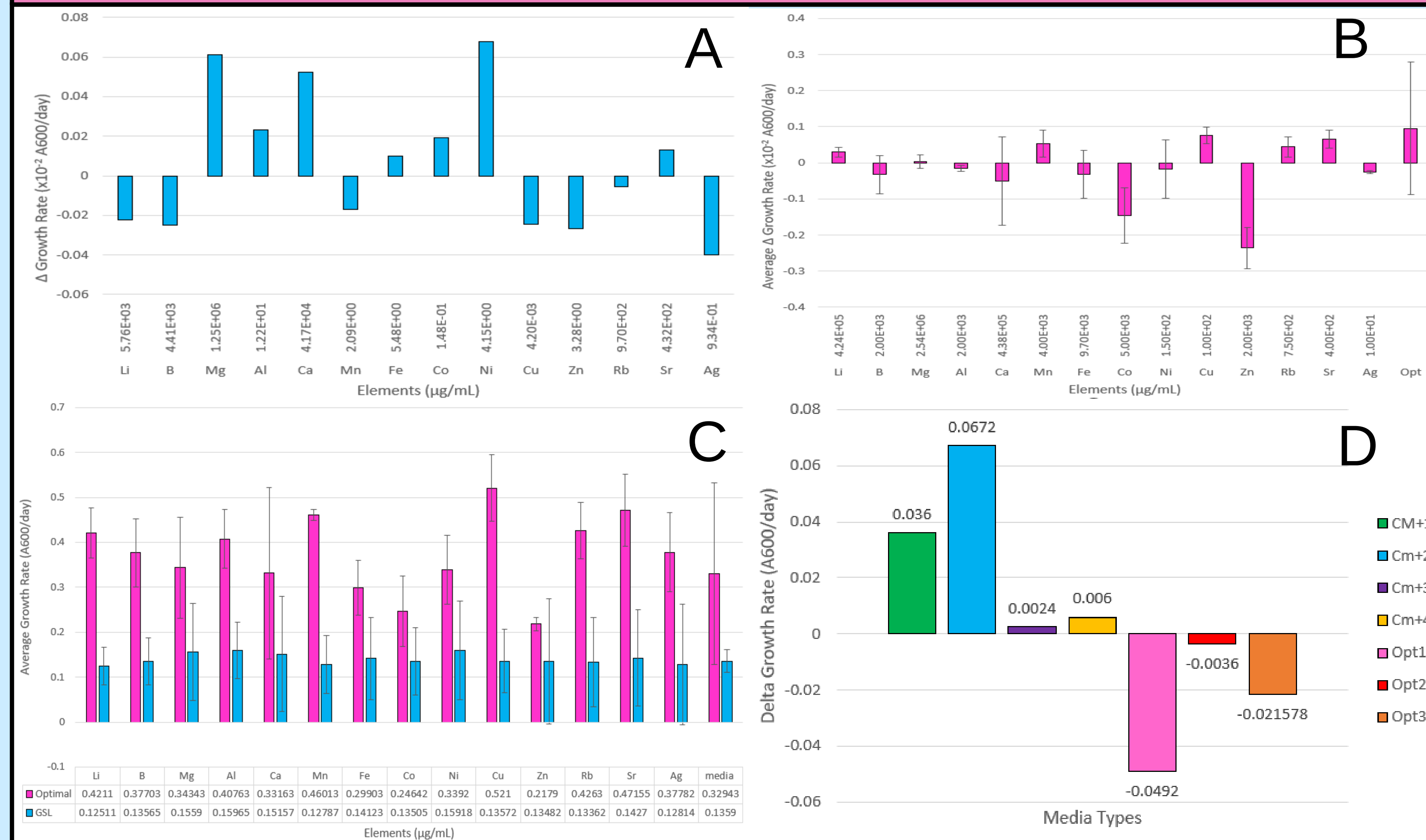


Figure 5: A) The change in *Halobacterium* growth compared with average negative controls of GSL concentrations of elements. At the GSL concentrations Ni, Mg, Al and Ca performed the best. The Ag did the worst. The GSL Media growth rate was worse than the controls' growth rate B) The change in *Halobacterium* growth compared with average negative controls of optimal concentrations of elements. For these cultures, most metals did reasonably well; however, some did worse than others, particularly Zn and Co. The optimal media growth rate exceeded the control growth rate. C) The optimal concentration growth rate (pink) vs. GSL concentration growth rate (blue). All the optimal concentrations had better cell growth rates than that of the GSL concentrations. D) The change in *Halobacterium* growth compared with negative controls of sunlight treated CM+ media and optimal media growth rates. In general, growing *Halobacterium* under artificial sunlight increased their growth rate. However, in the case of optimal media, it does not. This could be due to lack of gas vesicles being produced by *Halobacterium*. The optimal concentration cells have a standard deviation error bars calculated by averages, and the GSL-based media has error bars created by the linear function in Excel.

Conclusion

After testing group 1, 2 and transition metals, optimal concentrations for each were found by examining the average growth rate of the cultures. Not all metals were considered optimal. For example, silver is present in the GSL, but it did not increase the growth rate of Hs. While strontium consistently did better than the negative controls (traditional CM+ Media). The optimal concentrations of most metals were much higher than the concentrations in the GSL, except for Sr, Rb and B. To see if we could redesign the media, Hs cultures were grown at GSL concentrations and average growth rate can be seen in Figure 5. It shows that half of the metals performed above the control; Co, Fe, Ca, Al, Mg, Sr, with Ni doing the best. While the other half demonstrated a lower growth rate than the control; Cu, Zn, Li, B, Mn, Rb and Ag. However, they still grew relatively well at the GSL concentrations. A media was made by combining all the metals at the GSL concentrations, and the Hs growth rate did not outperform the control growth rate. To further explore how these metals might influence growth rate, we made a media at the experimentally determined optimal concentrations (figure 6). Most of the metals, performed better than the control; Li, B, Mg, Mn, Fe, Cu, Rb, Sr and Mn doing slightly better than the rest. The metals that did worse were Al, Ca, Co, Ni, Ag, and Zn. While we are not sure why most of the metals performed as they did, Ca might have performed worse due to the formation of a precipitate as the concentration increased. Metals that did not perform as well at the optimal concentration, generally did better at the GSL concentration, which was at a lower concentration. For the simulated sunlight testing, cultures grown in regular CM+ that underwent light treatment had a higher growth rate than those without sunlight. However, when our optimal media was used, the culture without sunlight had a higher growth rate (figure 8). This could be due to the fact the ones under the sunlight do not have gas vesicles thus making the optical density seem less. This can be seen in the color of the cultures. The next step is to repeat these experiments to replicate our results and fully understand how to optimally grow Hs.

Acknowledgments

- This project was supported by a 2022-2023 STEM Undergraduate Research Grant from the Higher Education Research Council. Department of Chemistry
- Office of Research
- Career Path Internship Program (CPI)
- Tyson Pattie, IAS Envirochem for Water Analysis

References

- Dundas, I. D.; Srinivasan, V. R.; Halvorson, H. O. A CHEMICALLY DEFINED MEDIUM FOR HALOBACTERIUM SALINARIUM STRAIN 1. *Can. J. Microbiol.* **1963**, 9 (4), 619–624. <https://doi.org/10.1139/m63-079>.
- Oren, A.; Litchfield, C. D. A Procedure for the Enrichment and Isolation of *Halobacterium*. *FEMS Microbiology Letters* **1999**, 173 (2), 353–358. <https://doi.org/10.1111/j.1574-6968.1999.tb13525.x>.

Final Report: Office for Research - SBOE Undergraduate Research Funding

Date: July 10, 2023

PI: Josh Grinath

Project: Elucidating effects of nitrogen pollution on plant nutrient content in sagebrush steppe ecosystems

Part 1

Description of Activities Undertaken: The research team completed three sub-projects with the overall theme of evaluating plant nutrient responses to nitrogen (N) pollution. Each sub-project was led by an undergraduate intern who presented their work as a poster at ISU's Undergraduate Research Symposium and Biology Research Roundup in Spring 2023. In the first sub-project, undergraduate Holly Forster analyzed the effects of long-term N pollution on the foliar carbon (C) and N chemistry of rabbitbrush, *Chrysothamnus viscidiflorus*. The second sub-project was led by undergraduate Kayla Hobbs, who assessed how legacy effects of previous long-term N pollution impacted the foliar chemistry of four plant species recovering from a wildfire (Hobbs won 'Best Undergraduate Poster' in the Biology Research Roundup). Lastly, undergraduate Madi Roth led the third sub-project evaluating spatial and temporal variation in the foliar C/N chemistry of six plant species occurring along Idaho roadsides. For each of the sub-projects, the undergraduate researchers prepared plant samples for chemical analysis using a standard protocol to grind foliar material into a fine powder, and then we sent the samples to ISU's Stable Isotope Laboratory for C/N analysis. Altogether, we accomplished the research goals outlined in the proposal, and we look forward to incorporating this work into future publications and grant proposals. This work will help to elucidate plant responses to N pollution and to inform the management of sagebrush steppe ecosystems.

In addition to the research activities described above, I mentored the undergraduate students to participate in the research community in my lab and in the Department of Biological Sciences. Prior to joining this research opportunity, I met with all three undergraduates and developed individualized 'mentoring compacts' that outlined mutual expectations for the mentor and mentee. These compacts were living documents subject to revision and served as a starting point for the mentoring relationships. The students also signed contracts describing technical details of the research positions and a commitment to participate in our Plant C/N Working Group. The undergraduate researchers met with the PI weekly during lab meetings and working group meetings, and the PI met with the undergraduates individually approximately every other week through the Spring 2023 semester. During the working group and individual meetings, we discussed primary literature on N pollution and associated plant responses, learned how to conduct and interpret statistical analyses, and workshopped posters presenting the results of their sub-projects. The lab meetings provided additional opportunities for the students to learn about the ecology of sagebrush steppe ecosystems, from soils and microbes to plants, insects, and birds. These meetings also engaged the students in scientific discourse with the PI, graduate students, and fellow undergraduates in the lab. Furthermore, the undergraduate researchers attended the Biological Sciences Seminar Series and other department events (e.g. graduate student proposals and defenses). These activities engaged the students with the research community across the Department of Biological Sciences, as well as with a variety of research topics spanning biology.

All three students completed CITI Responsible Conduct of Research training as a requirement of their internships. Throughout the research experiences, we stressed the importance of clear communication, professional cooperation, and showing respect to all in the workplace. The students learned how to maintain a clean and safe lab environment in which researchers support one another to accomplish shared goals. For instance, when one student completed their work early, they helped the other students to prepare the plant samples for C/N analyses for their sub-projects.

How the Project Benefitted from the Funds: This grant supported 1) three undergraduate interns, 2) an early career faculty in the Department of Biological Sciences, and 3) the collection of data for three sub-projects that will contribute to larger research projects in the Grinath Lab.

The funds supported salaries for three undergraduate women (Holly Forster, Kayla Hobbs, Madi Roth) to participate in research. These students would not have been able to gain this research experience without financial support. Two of the interns graduated in May 2023 (Hobbs, Roth) and the third intern will graduate in December 2023 (Forster). The Undergraduate Research Funding was critical for developing the research and communication skills of the undergraduates, who each developed and presented a poster on their work. All three students received responsible conduct of research training through discussion in weekly lab/working group meetings, individual meetings, and the RCR CITI training modules. Other trainings included lab safety, mentor-mentee relationships, and data management. Two of the sub-projects are contributing to senior theses by Roth and Forster as part of their Biology coursework (BIOL 4493), which we intend to develop into manuscripts for publication in peer-reviewed journals. As the projects continue to develop, all three students will continue to have opportunities to participate in manuscript writing and research dissemination in the primary literature. These experiences helped to prepare the students for graduate school and biological careers.

This project has aided the research productivity of PI Grinath, an early career faculty member (Assistant Professor) in the Department of Biological Sciences. All three of the sub-projects described above are part of larger projects within the Grinath Lab, and their completion helped to move those projects forward. The first sub-project (Forster) will inform a study on the responses of rabbitbrush plants and their associated arthropods to thirteen years of N pollution. The second sub-project (Hobbs) will inform an experiment evaluating how legacies of N pollution impact plant recovery following wildfire. Lastly, the third sub-project (Roth) will inform a study on spatial and temporal variation in plant traits during roadside restoration. These projects will lead to multiple published research products, and they will help in preparing proposals for future research activities. Currently, I am preparing a CAREER proposal for submission to the U.S. National Science Foundation (NSF), and the results for the rabbitbrush study are aiding the development of this proposal.

How the Research Goals of the Project were Furthered: The funding has enabled our team to test multiple hypotheses about plant responses to N pollution. While the sub-projects were united by a common theme of evaluating responses to N pollution, they also contributed to several larger projects in the Grinath Lab. This work would not have been possible without SBOE HERC funding due to time and financial constraints for the undergraduate researchers and for the

PI. The funds primarily supported hourly wages for the undergraduate students, and no additional funds were available to support wages for these students to complete their research tasks.

There were several challenges that the research team faced, which will inform future research activities. First, we learned that grass leaves are much more difficult to prepare for chemical analysis than wildflower and shrub leaves. Our original estimate for time required to grind plant samples into a fine powder for C/N analyses was based on analyses of the leaves of rabbitbrush, which is a shrub with leaves that are easy to grind. Grass leaves contain large quantities of grinding-resistant silica and require additional processing to chop leaves into small pieces prior to finally grinding into a powder. Therefore, plant grinding for two of the sub-projects (which included grass species) took longer than originally expected. The student working with rabbitbrush finished preparing their samples early, and then they aided the other students with preparing samples for their sub-projects. Related to this delay in preparing samples, the other main challenge was that the team did not receive plant C/N results from the Stable Isotope Laboratory until after the students presented their posters. To prepare results for the poster presentations, the students worked with PI Grinath to analyze additional results for each of the larger projects to which their sub-project contributed. This helped the students to put their research into the larger contexts of these projects, but was a bit disappointing to the students because they wanted to present the results of their labor. In the future, I will be better able to estimate the time required for these research tasks and will aim to complete sample preparation and analysis of plant C/N chemistry prior to disseminating these results in poster presentations.

The last challenge was that, initially, the students were mistakenly set up with Temporary Employee (TMP) positions instead of Student Non-Work Study (STU) positions. This was an issue because fringe benefits for STU positions are less than that for TMP positions and more of the budget was used to support fringe benefits than originally planned. This mistake was corrected after the first couple weeks of the internships, but it caused some confusion for the students in entering their hours and for the PI in planning the budget. Clearer instructions for setting up the student positions would help to alleviate this issue in the future.

Part 2 – Student Reports

SBOE 2023 Undergraduate Intern - Report for ISU's Office for Research

Project: Elucidating effects of nitrogen pollution on plant nutrient content in sagebrush steppe ecosystems

Faculty Lead & Mentor: Josh Grinath

Student Name: Holly Forster

Date: 04/30/2023

What did you learn from your internship experience?

I learned..

- The importance of the nitrogen cycle and how nitrogen deposition affects foliar chemistry.
- How crucial it is for biologists to network and talk to each other not only for advice and resources but as friends.
- How to present ongoing research to a scientific community and a non-scientific community.
- How to interpret statistical data.
- How to participate and engage better in group settings.
- More about research etiquette.
- How to collaborate in the lab with other individuals with different levels of education and degree focuses.
- How to collect data and to analyze it.
- How to grind plant material and how it is processed for data.
- How to work in a lab rather than just the field.

How did this research experience benefit you?

This experience benefitted me in numerous ways, but most importantly it built my confidence as a woman in STEM as well as a first-generation college student. I have acquired new tools that I know I am going to be able to apply in the future, whether that be here at ISU or future endeavors. I have had experience in the field, but never in the lab, so to me, this experience was important and pertinent to my degree to really determine if this is something I want to continue pursuing.

How has this research experience changed your future plans, if at all?

This experience has encouraged me to stay in this field and to not give up. I could only be so lucky to continue working with bright and passionate individuals such as Dr. Grinath or any of the lovely coworkers I had during the semester. I'm very thankful that I was given this opportunity.

Effects of Long-Term Nitrogen Deposition in a Plant-Arthropod Community

Holly R. Forster*, Joshua B. Grinath

Department of Biological Sciences, Idaho State University, Pocatello, Idaho

Introduction

- Humans have altered the nitrogen (N) cycle by increasing atmospheric nitrogen deposition, which has fertilization effects on recipient ecosystems.¹
- While impacts on plants are well documented², animal responses to this N pollution are less clear, especially over the long time periods typical of chronic N deposition.³⁻⁵
- Stoichiometric theory predicts that herbivores will benefit from increased plant nutritional quality (higher foliar N, lower foliar C:N ratio) in N-enriched conditions.⁶
- We investigated effects of long-term N deposition on a plant-arthropod community using a N addition experiment in a sagebrush-rabbitbrush steppe ecosystem.^{7,8}

Objective

- Here, we evaluated responses of rabbitbrush (biomass, foliar N and carbon) and its insect herbivores to 13 years of N enrichment.



Plant-sucking treehoppers are the numerically dominant herbivore species on rabbitbrush and are protected by mutualist ants.

Methods

- We studied rabbitbrush (*Chrysothamnus viscidiflorus*) in 32 plots that either had ambient N deposition (2kg N/ha/yr) or had simulated rates of enriched N deposition (7kg N/ha/yr) from 2010 to 2022 in Almont, Colorado.
- 62 plants were evaluated for their foliar N and carbon (C) in year 3 of the experiment and have been resampled in the 13th year to evaluate whether foliar chemistry had changed.
- In 2022, we surveyed arthropod abundances on each plant, as well as chewing insect (beetles, caterpillars) damage to leaves.
- We estimated plant aboveground biomass by converting plant volume using an allometric curve.⁹
- Analyses of responses to N enrichment were conducted using general linear mixed models (GLMMs) in R v4.2.2.



Idaho State University

*Contact: forshall@isu.edu

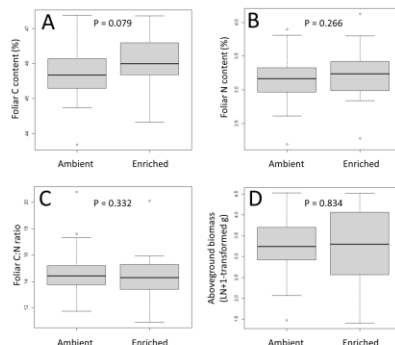


Figure 1. Plant responses to nitrogen enrichment. Data are shown as boxplots with P-values for the N-enrichment effect.

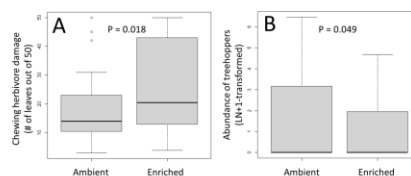


Figure 2. Herbivore responses to nitrogen enrichment. Data are shown as boxplots with P-values for the N-enrichment effect.

Acknowledgements

- We thank M. Roth, D. Erickson, J. Godinez, and J. Jackson for research assistance.
- Funding support was provided by a STEM Undergraduate Research Grant from Idaho State Board of Education through ISU's Office for Research, EPA STAR Fellowship FP-917309, fellowships (Snyder, Graduate) from the Rocky Mountain Biological Laboratory, and ISU's College of Science and Engineering and Office for Research to JBG.
- This work was conducted on the traditional lands of the Uncompahgre (Tabeguache) Band of the Ute people.

Results

- In the 3rd year, there were no significant differences in foliar C content, N content, and C:N ratio between ambient-N and enriched-N plots (Fig. 1A-C), though there was a tendency for C content to be higher in enriched conditions.
- In the 13th year, the plants did not differ in aboveground biomass (Fig. 1D).
- Total herbivore abundances did not differ between ambient-N and enriched-N conditions ($P = 0.722$).
- However, chewing herbivore damage to the plants was greater (Fig. 2A) and plant-sucking treehoppers were less abundant (Fig. 2B) in enriched-N plots.

Discussion

- Our results suggest that different herbivores (chewing and sucking) respond in different ways to nitrogen deposition.
- We are currently awaiting foliar chemistry results from 2022 and will evaluate whether changes in foliar C content, N content, and C:N ratio have occurred, and whether foliar chemistry is correlated with changes in herbivore abundances and damage to plants.
- Further work is also needed to evaluate predatory arthropod responses, such as ladybeetles and ants.
- Animal responses to long-term N deposition may need to be considered in addition to plant responses.



Predatory lady beetle searching for insect prey on rabbitbrush flowers.

References

- Vitousek PM, et al. 1997. *Ecological Applications* 7:737-750. doi: 10.1890/1051-0761(1997)007[0737:HAOTONG]2.0.CO;2
- Balshovik R, et al. 2010. *Ecological Applications* 20:30-49. doi: 10.1890/1061-1540.1
- Thropo HL, & Lerdau MT. 2004. *Ecosystems* 7:109-133. doi: 10.1007/s10021-003-0225-x
- Meunier CL, et al. 2016. *Global Change Biology* 22:164-179. doi: 10.1111/gcb.12967
- Stevens CJ, et al. 2018. *Functional Ecology* 32:1757-1766. doi: 10.1111/1365-2445.13063
- Schnitzer RW, & Elser JJ. 2002. *Ecological Stoichiometry*. Princeton University Press, Princeton, NJ.
- Grinath JB. 2018. *Ecology and Evolution* 8:1213-1223. doi: 10.1002/evl.4393
- Grinath JB. 2021. *Acta Oecologica* 110:103706. doi: 10.1016/j.acto.2021.103706
- Grinath JB, et al. 2015. *Ecology Letters* 18:164-173. doi: 10.1111/ele.12396

SBOE 2023 Undergraduate Intern - Report for ISU's Office for Research

Project: Elucidating effects of nitrogen pollution on plant nutrient content in sagebrush steppe ecosystems

Faculty Lead & Mentor: Josh Grinath

Student Name: Kayla Hobbs

Date: May 16, 2023

What did you learn from your internship experience?

During this internship, I learned how to grind plant samples. I also learned how to improve my poster design and writing skills. We discussed primary literature, and learned how to apply it to our work. I now feel that I have a better understanding of creating and presenting posters, as well as nitrogen processes.

How did this research experience benefit you?

I believe that writing and presenting skills gained from this experience will benefit me most in the future. We spent a good amount of time editing and revising our posters, as well as giving mock presentations to fellow lab members, which I found very helpful. I also feel that doing student research projects has given me a small glimpse of what my future education may look like. I felt that lab meetings and discussions were very beneficial for my future understanding of applying literature, conducting research, and presenting research.

How has this research experience changed your future plans, if at all?

This experience has not necessarily changed my future plans. However, I do feel like skills I have gained through this experience will benefit me in my graduate studies.

Legacy effects of nitrogen addition on plant cover and chemistry during post-fire recovery

Kayla Hobbs*, Joshua B. Grinath, Department of Biological Sciences, Idaho State University, Pocatello, Idaho

Introduction

- Humans have dramatically altered the nitrogen (N) cycle, particularly by increasing atmospheric N deposition, resulting in changes in plant assemblages.¹⁻³
- However, lasting effects of this N pollution after cessation require long-term study and are often unclear.⁴⁻⁶
- In recent years, wildfires have become more widespread throughout the Western US, causing a growing need to understand plant recovery post fire.⁷⁻⁹
- At present, it is unclear how legacy effects of N deposition impact plant assemblages recovering from wildfire.

Objective

- In this study, we evaluated how legacies of N deposition impact plant cover and chemistry in a sagebrush steppe ecosystem following wildfire.



Map of Barton Road Ecological Research Area

Methods

- This study was conducted at the Barton Ecological Research Area in Pocatello, Idaho.
- Elevated N deposition was simulated in 6 plots (plus 6 control plots) from 1997 to 2010. Treatments of N addition were randomly assigned one of three levels: 0, 6, and 12 kg N/ha/year (white, light-blue, & dark-blue plots in above map).
- In 2021, we measured plant species cover and collected the most abundant plant species for foliar chemistry analysis: A. *Kochia* (*Bassia scoparia*), B. *Sego Lily* (*Calochortus nuttallii*), C. *Bluebunch Wheatgrass* (*Pseudoroegneria spicata*), and D. *Western Salsify* (*Tragopogon dubius*). See images to right.
- Foliar samples were ground to fine powder and sent to ISU stable isotope lab for carbon and nitrogen analyses.
- We analyzed cover of these plant species in relation to N treatments and microhabitat variability created by shrubs using GLMMs in R v 4.2.2 for count data.



Idaho State University

*Contact: hobbkayl@isu.edu

Results

- N enrichment had a negative effect on the cover of Sego Lily, but not the other species.
- In three of the four species, cover was higher in intershrub areas than in areas in which shrubs formerly occurred.

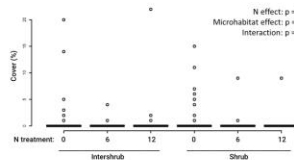
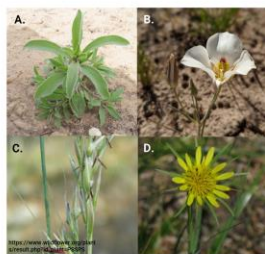


Figure 1. *Kochia* did not respond to N treatments nor microhabitats.



Study species at Barton Ecological Research Area

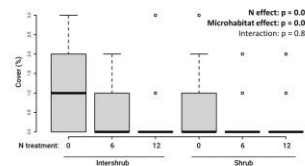


Figure 2. Sego Lily had lower cover with N addition and under former shrubs.

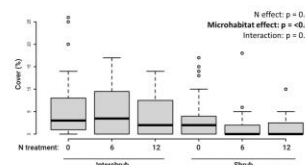


Figure 3. Bluebunch Wheatgrass had lower cover under former shrubs, but did not respond to N treatments.

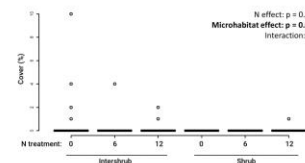


Figure 4. Western Salsify had lower cover under former shrubs, but did not respond to N treatments.

Discussion

- We are currently awaiting results for foliar chemistry.
- We anticipate that of the four study species, Sego Lily may have relatively lower foliar N content because it was the only species negatively affected by N addition.
- These legacy effects may deserve greater attention due to potential impacts on ecological trajectories, such as plant recovery after fire.

Acknowledgements

- We thank T. Kermer, E. Stewart, C. Dirickson, M. Roth, D. Lugo Cordero, A. Rasmussen, N. Nunoo, A. Robinson, and S. McArthur for research assistance.
- Funding support was provided by NSF DEB 2118125 and a STEM Undergraduate Research Grant from Idaho State Board of Education through ISU's Office for Research.
- This work was conducted within the boundaries of the original Fort Hall Reservation on the traditional lands of the Shoshone and Bannock peoples.

References

- Vitousek PM, et al. 1997. *Ecological Applications* 7:727-750. doi: 10.1890/1051-0761(1997)007[0727:MAKOTON]2.0.CO;2
- Fenn ME, et al. 2003. *BioScience* 53:404-420. doi: 10.1641/0090-3548(2003)053[0404:EDNDG]2.0.CO;2
- Bobbink R, et al. 2010. *Ecological Applications* 20:30-49. doi: 10.1890/081140.1
- Clark CM, & Tilman D. 2008. *Nature* 455:712-715. doi: 10.1038/nature06503
- Idell F, et al. 2013. *Ecology Letters* 16:454-460. doi: 10.1111/lel.12066
- Bosman WO, et al. 2018. *Ecological Applications* 28:1762-1772. doi: 10.1002/eaag.1789
- D'Antonio CM, & Vitousek PM. 1992. *Annual Review of Ecology & Systematics* 23:63-87. doi: 10.1146/annurev.es.23.110192.000431
- Liu Y, et al. 2010. *Forest Ecology & Management* 259:685-697. doi: 10.1016/j.foreco.2009.09.002
- Schuster MJ, et al. 2018. *Journal of Applied Ecology* 55:2362-2373. doi: 10.1111/1365-2664.13195

SBOE 2023 Undergraduate Intern - Report for ISU's Office for Research

Project: Elucidating effects of nitrogen pollution on plant nutrient content in sagebrush steppe ecosystems

Faculty Lead & Mentor: Josh Grinath

Student Name: Madison Roth

Date: April 30, 2023

What did you learn from your internship experience?

I learned how to write a procedure, train colleagues, design/conduct an experiment, collect/analyze data, create/present a research poster, and investigate primary literature to write a thesis.

How did this research experience benefit you?

I've been thinking about a career in biological research for a long time, and this experience gave me the chance to try it out first-hand. I'm grateful to have had the opportunity to conduct a research project in my undergrad, as opposed to committing to a research project in graduate school never having had a real experience to show me if I would even enjoy it.

How has this research experience changed your future plans, if at all?

This research experience hasn't changed my future plans, but it has informed it. I feel more confident in moving forward with research opportunities to explore my interests in certain specialties. I also feel confident that if I do continue my education, I'll go into a master's program more knowledgeable and prepared than I would've if I hadn't had this experience.

Intraspecific Trait Variation Among Plants During Roadside Restoration

Madison Roth*, Erika Stewart, & Joshua B. Grinath

Department of Biological Sciences, Idaho State University, Pocatello, Idaho

Introduction

- The loss and degradation of habitats due to species invasion is a problem in ecosystems around the world^{1,2}.
- Identifying native species that can institute biotic resistance via limiting similarity is important for restoration³⁻⁵.
- Trait-based models can aid in identifying native plants that occupy similar niches as and compete with invasive species⁶⁻⁷.
- However, these models often use mean trait values for both invasive and target species, assuming intraspecific trait variation (ITV) is unimportant⁷.
- ITV can cause complications in applying such models due to potential spatial and temporal variation⁸.
- Understanding ITV in the context of location, time, and ontogeny is a key knowledge gap in restoration efforts.

Objective

- In this study, we evaluate ITV in the context of space, time, and the interaction of space and time during initial plant restoration.



Methods

- Established Roadside Revegetation Project (ITD) at three sites.
- In June and September 2022, we measured traits of common invasive and native species at each site.
- Species consisted of
 - Native forbs: common yarrow (*Achillea millefolium*), blue eyed mary (*Collinsia parviflora*), and annual sunflower (*Helianthus annuus*)
 - Invasive forbs: kochia (*Bassia scoparia*) and prickly lettuce (*Lactuca serriola*)
 - Invasive grasses: crested wheatgrass (*Agropyron cristatum*) and smooth brome (*Bromus inermis*)
- Height was measured in the field. Height is associated with competitive ability. Specific Leaf Area (SLA) was found later in lab by dividing one-sided leaf area by leaf's dry mass. SLA is representative of growth strategy.
- Data were analyzed with GLS and GLMM and in R v4.2.2.

Results

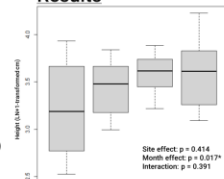


Figure 1. Height of crested wheatgrass.

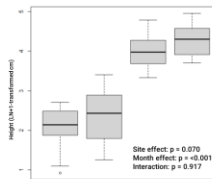


Figure 2. Height of kochia.

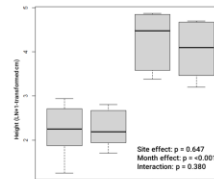


Figure 3. Height of annual sunflower.

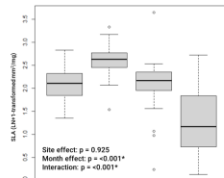


Figure 4. SLA of crested wheatgrass.

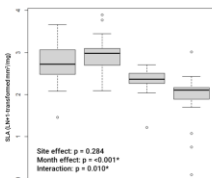


Figure 5. SLA of kochia.

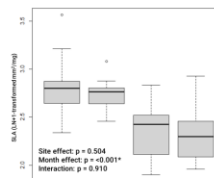


Figure 6. SLA of annual sunflower.

Discussion

- General trend for height to increase over time
 - Only month was significant
- SLA decrease from June to September
 - More conservative resource use as plants age
 - Strong effect of month; significant interaction or site effect in some cases
 - May need to evaluate based on individual species
- Our results suggest that it may be important to account for ITV in restoration



Madison Roth and Erika Stewart at Inkom field site.

Acknowledgements

- We thank K. Reinhardt and K. Turner for contributing equipment and supplies.
- We thank E. Stewart, T. Harris, C. Kay, E. Christen, R. Blouhorm, K. Hobbs, H. Forster, H. Clawson, M. Leonard, C. Forshee, and D. Lugo Cordero for research assistance.
- Funding support was provided by the Idaho Transportation Department and an Undergraduate Research Grant from the Idaho State Board of Education (ISBE) through ISU's Office for Research.
- This work was conducted on the traditional lands of the Cayuse, Umatilla, Walla Walla, Shoshone-Bannock, Ute, and Eastern Shoshone people.

References

- Thompson et al., 2021. Conservation Science and Practice, e533. doi: 10.1111/csp2.533
- Nevo et al., 2015. Arab. J. Sci. doi: 10.1007/s12010-015-0278-2
- Brooker et al., 2004. BioScience, 54, 477-488. https://doi.org/10.1641/0006-3568(2004)054[0477:ESAPSC]2.0.CO;2
- Schuster et al., 2018. Journal of Applied Ecology, 55, 2262-2273. doi: 10.1111/1365-2664.13195
- MacArthur & Levins, 1967. The American Naturalist, 101, 377-385. https://doi.org/10.1086/282585
- Funk et al., 2008. Trends in Ecology & Evolution, 23, 695-703. https://doi.org/10.1016/j.tree.2008.07.015
- Laughlin, 2014. Ecology Letters, 17, 771-784. https://doi.org/10.1111/ele.12288
- Funk et al., 2021. Annals of Botany, 127, 495-503. https://doi.org/10.1093/aob/mcab106



Idaho State University

*Contact: rothmadi@isu.edu

Part 3 – Report of Expenditures

Index for Expenditures: ABIO07

The three undergraduate internships occurred from January 9 to May 5, 2023, and the interns were compensated with hourly wages (\$13.00/hour). Students worked according to a pre-set schedule in order for wage expenditures to be dispersed evenly through the semester and for all three interns to receive equal pay. The interns worked several hours more than originally budgeted, resulting in slightly higher wage expenditures than planned (see below). In addition, the students were initially set up with TMP positions, and then were set up with STU positions for the majority of their internships. This resulted in higher fringe expenditures than originally planned because TMP positions are assessed a higher fringe rate (10.5%) compared to STU positions (3.7%). After accounting for the above, the remainder of the budget supported foliar C/N analyses conducted at ISU's Stable Isotope Laboratory. This included the analysis of 49 samples at a rate of \$9.50 per sample.

Original Budget:

1. Wages = \$13.00/hour x 180.5 hours/student x 3 students = \$7,039.50
2. Fringe = 3.7% x \$7,039.50 = \$260.50
3. Research travel = \$0
4. Materials and supplies = \$700.00

Total = \$8,000

Actual Expenditures:

1. Wages = \$7,182.50
2. Fringe = \$353.25
3. Research travel = \$0
4. Materials and supplies = \$465.50

Total = \$8,001.25

Final Report on the “Genome Annotation and Analysis of Novel Bacteria” project at ISU and funded by a HERC funding grant to Professor Peter Sheridan, Department of Biological Sciences.

November 17, 2023

Executive Summary: Using the funds generously provided by the HERC grant, I was able to partially sequence the genomes of 10 novel Bacteria and train 2 graduate students in the processes of genome sequence clean-up, assembly, and annotation. The 2 graduate students were then able to write comprehensive reports on the genome annotation of one of the Bacteria. Although due to the incompleteness of the genome sequence they were not able to produce publishable manuscripts, the students were trained in a variety of sequence manipulation and annotation techniques. Both graduate students are now employed in the biotechnology careers and are using the skills gained during this project. As we were unable to comprehensively sequence the Bacterial genomes, I did not incorporate undergraduates in the genome assembly and annotation efforts due to the fact that they would not have the required background to understand partial genome analyses (which were quite difficult for even the graduate students to attempt, despite their greater biochemical and microbiological knowledge bases). In order to give a large cohort of students a meaningful research experience, I trained over 6 undergraduates in a project to isolate novel bacteriophage (bacterial viruses) from a variety of samples. I have attached PDF files to this report containing feedback from the students regarding their research experiences.

1. A description of the activities undertaken, how the lab/project benefited from the funds, how the research goals of the lab/project were furthered.

The original intent of the HERC funds were to submit DNA isolated from 10 novel Bacteria (isolated from Antarctic samples and Grand Teton National Park samples) to the ISU Molecular Research Core Facility for genomic DNA sequencing on their Illumina MiSeq instrument. We used approximately \$6000 in HERC funds to have two sequencing chips run. The first chip gave results for some of the samples and the low quality results of some of the genome sequences led to us re-submitting some samples for sequencing on the second chip. I had high confidence that we would be able to achieve complete or nearly complete genome data due to the redundancy of our sequencing efforts. Standard sequencing protocol is to sequence a genome at 5X -15X coverage (i.e., if your target genome is 1 million basepairs long you need to sequence between 5 million to 15 million bases to get total coverage). The sequencing chip used by the MRCF would provide approximately 1 million reads of about 400 basepairs of sequence (or 400 million basepairs) for each of the 10 genomes (see information in the attached MRCF quote *P.Sheridan (10) NEB Ultra DNA 500cycle 09-12-22*). Bacterial genome sizes vary, but are usually in the 3-5 million basepair range although some are as large as 10 million basepairs. We had identified our novel Bacteria using 16S gene sequencing so we knew an approximate size of their genomes from that of close relatives that had been sequenced. Even if all 10 novel Bacteria had genomes of 10 million basepairs, we would be sequencing at 40X coverage (400 million/10 million), which is well above the standard. Actual results produced by the MRCF were well below this. I have repeatedly submitted genome sequencing projects to the ISU MRCF and have always been underwhelmed by the results. At this point, I will be submitting any future genome sequencing to outside companies that specialize in this.

Nevertheless, I recruited two graduate students (Jake Shields and Katelynn Miller) to work with me on the genomic sequencing and annotation of the novel isolates. They worked with me to grow up large scale cultures of the Bacteria and isolate genomic DNA. We then submitted this for sequencing at the MRCF. I picked one of the novel Bacteria to assemble and annotate with the students based on the resulting data files. We proceeded with the annotation knowing that we were only able to produce large, but partial, contigs (contiguous sequences) from the data results provided by the MRCF. We used the Galaxy

software platform (<https://usegalaxy.org/>) to clean-up, filter and join the sequences and to assemble them into contiguous sequences. For assembly, we used the Unicycler, IDBA-UD, Shovill, and SPAdes programs on Galaxy. We submitted the large contigs to the RAST Rapid Annotation using Subsystem Technology platform (<https://rast.nmpdr.org/>) along with the sequenced genome of a closely related Bacterium as a “guide” genome for annotation. I had the students interpret the resulting annotation results to determine the biochemical and metabolic capabilities of the novel Bacterium (as best they could for a partial genome) with respect to the closely related organism. I had them see if the novel Bacterium (closely related to *Flavobacterium plurextorum*) had the genes for complete metabolic pathways for glycolysis, the citric acid cycle, the pentose phosphate pathway, the electron transport system, the F₀F₁ ATP Synthase, lipid synthesis and breakdown, DNA replication, RNA replication, and translation. I also had the students look for any unusual secondary metabolic pathways (i.e., metal ion resistance, radiation resistance mechanisms, antibiotic resistance genes, etc). The students wrote comprehensive analyses of their annotations of the novel *Flavobacterium plurextorum* isolate (files submitted with this report as: **JShields Genome Annotation Report**, **KMiller Genome Annotation Report**, **KMiller RAST Pathway Images**, and **KMiller Pathway Tables for Report**). Had we been able to get sufficient genome coverage from the MRCF, these analyses would have been combined into a single manuscript and submitted for publication.

The undergraduates needed to have an intensive bench-based research experience, so I decided to try to enrich for and isolate novel bacteriophage from a variety of environmental samples. Zoo Pocatello graciously provided me with a variety of fecal samples from bison, grizzly bear, elk, mule deer, and pronghorn antelope. We used these samples to enrich for bacteriophage capable of lysing *Escherichia coli* strain O157:H7. The motive for this research was to train the students in the safe usage of pathogenic bacteria and to learn how to work with viruses. The Department of Biological Sciences has recently gotten rid of the virology lab that was in the Microbiology B.S. degree curriculum, so students really had little chance to work with viruses in a research lab setting. We were quite successful in obtaining bacteriophage capable of lysing *E. coli* O157:H7 from the grizzly bear fecal samples and are continuing the characterization of these bacteriophage. I am in discussion with some of the undergraduate students about turning the determination of the host range specificity of the bacteriophage and their potential as disinfection agents in M.S. in Microbiology graduate projects.

Although the genome sequencing portion of the work was not as successful as hoped, I still got useful partial data that may be incorporated into grant applications to finish the genomic sequencing of these novel Bacterial isolates. This sequencing would NOT be done in the ISU MRCF. The bacteriophage portion of the research was extremely successful, and I have 5 of the undergraduates still working with me 1 year later. Three are considering graduate school at ISU.

2. Student reports.

I asked that undergraduates to write brief summaries of their experiences working with me on the bacteriophage project. Due to their hectic schedules, I was able to get 3 reports back from the students and they are submitted with this report as: **Austin Robison Report**, **Braelyn Krosschell Report**, and **Phage Report_Nestler_Jayden**). As you can see from the reports, working with me directly in my laboratory has had an extremely positive effect on these students. As a matter of fact, Austin Robison decided to apply to graduate school at ISU and is currently an M.S. in Microbiology student in my lab. His project has nothing to do with bacteriophage, but actually uses some of the partial genomic data we were able to generate from another one of the novel Bacterial isolates and he is currently cloning the gene for and expressing an enzyme for characterization. Braelynn and Jayden are both considering

applying to graduate school at ISU to work with me on either bacteriophage projects or perhaps enzymes from the novel Bacterial isolates. In summary, the research experience for the students has benefitted both them and myself.

3. A report of expenditures.

The attached Excel spreadsheet (*2023.11 ABIO06 Total Expenditures for FY23*) gives a summary of the expenditures of the awarded funds. Most was spent on the less than stellar sequencing conducted by the ISU MRCF (about \$6000), with approximately \$4000 spent on lab supplies (kits, media, consumables) and about \$800 spent on student salaries over the Summer to grow the novel Bacteria and isolate genomic DNA. Of the \$10,235 awarded, \$10,064.14 was spent, which means we underspent the awarded funds by \$170.84.

I learned about the interactions between bacteriophages and their target host species. In our work, we isolated novel bacteriophages from a variety of samples with the goal of testing their host range specificity, meaning how many and which bacteria they could successfully infect. I also learned that bacteriophages are becoming an increasingly researched topic as they could be the answer to a decrease of antibiotic effectiveness. During this opportunity I both honed old skills and learned new ones such as media preparation, serial dilutions, mass organization and labeling, observation of plaque formation, and both bacteria and virus inoculation techniques.

This research was beneficial to me because it allowed me to understand a topic of research within microbiology that I had only ever had a lecture-based class on. Being able to go into a laboratory setting where the professor is there to help teach you advanced techniques with hands on experiences solidified my understanding of these topics. Not only that but it allowed me to see how other research laboratory's function. During my time doing this research I was taught from Dr. Sheridan himself, rather than another undergraduate or graduate student teaching me techniques like I had experienced in other labs. This experience solidified my future plans of graduate school as it showed me yet again how fascinating microbiology is and the resource it is for solving modern problems.

Braelyn Krosschell

Being in Dr. Sheridan's lab has taught me about the research process overall, as well as what it takes to be a researcher. I have learned about the steps that it takes to ensure that the research and data are valid, such as documenting the process and maintaining an aseptic environment as to not contaminate the biological samples. I have also observed how a lab is run and what materials are used. I have observed and had hands-on experience with new techniques that I did not previously know of or have exposure to. Dr. Sheridan is very knowledgeable and can eloquently explain new concepts to me in a way that is both interesting and easy to understand. He often asks us questions and ensures that we comprehend each small component of the overall big picture. Due to this, I am constantly learning new things and absorbing new, valuable information.

My experiences in this lab have also greatly benefited me. One example of this is how I feel much more prepared when attending a lecture or lab for class credit. In lecture, when a professor is explaining research techniques and methods, it is helpful to have this experience under my belt. I can follow along and gain a deeper insight into the lecture material much easier than if I didn't have experience in a research lab. In the classroom labs, I feel confident and well prepared when conducting experiments. I am able to perform laboratory tasks with ease and certainty. Another way that I have benefited from my experience in this lab is when applying to graduate school. I feel that I can articulate myself well and demonstrate that I have a deep understanding of a laboratory setting when asked during the application process. This experience not only peaks the interest of those who look at my application for graduate school, but will also allow me to showcase my abilities when asked and when introduced to a new lab environment.

This experience may not have changed my future plans, however, it has made me feel confident in my decision to change my future plans prior to working in this lab with Dr. Sheridan. Shortly before joining this research lab, I made the decision to apply to the master's program and get a master's degree before continuing onto dental school. I had wondered if I made the right choice up until I gained valuable experience in this lab. Because of all the things I have observed and learned, I now feel that I made the correct decision. I have enjoyed my experiences being a part of a research lab and am glad to have this amazing opportunity. I greatly look forward to getting a master's degree and continuing to gain knowledge as I progress forward.

Genomic Assembly and Annotation of a novel Antarctic isolate related to *Flavobacterium plurextorum*

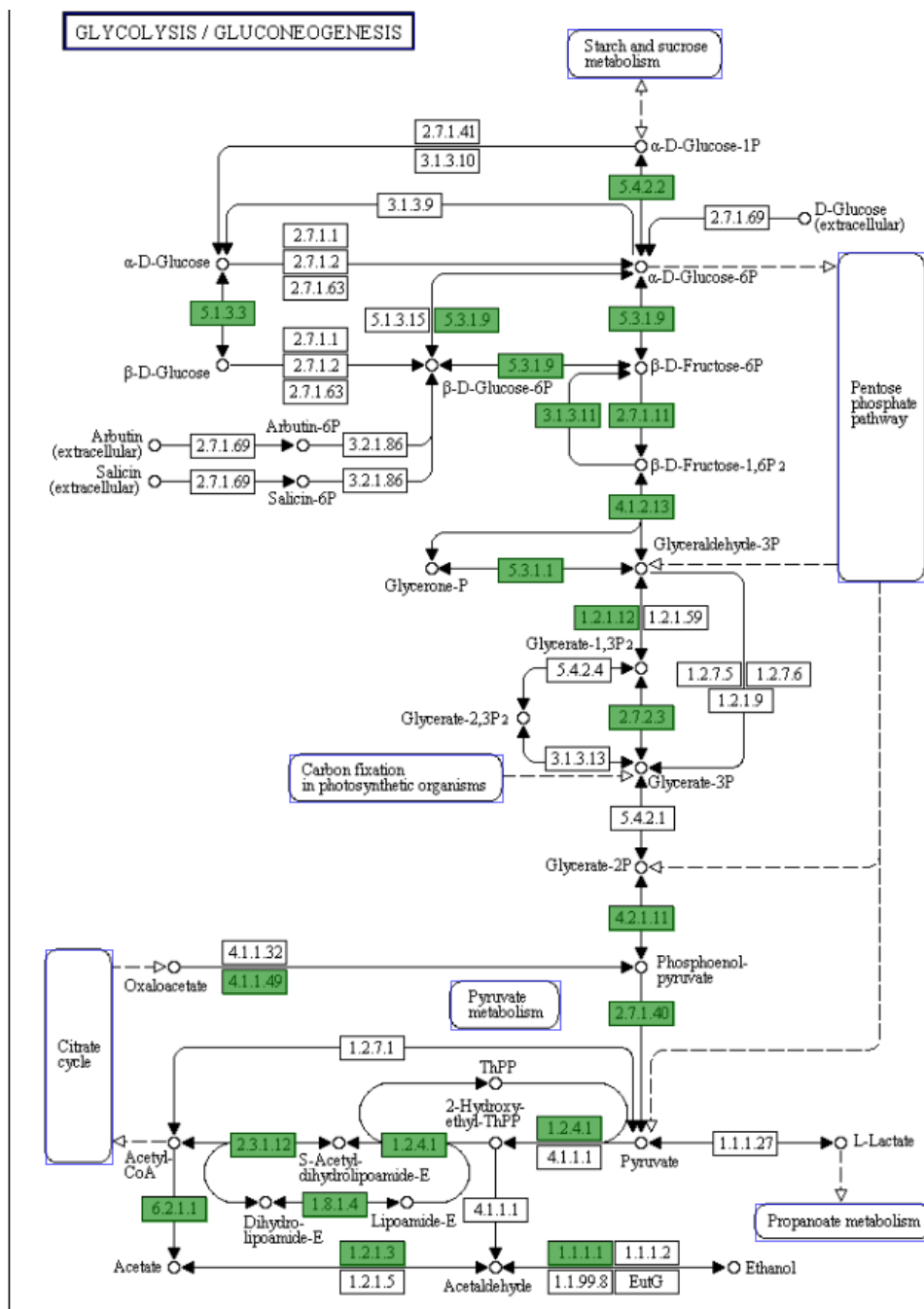
Important Note: In the instance any major metabolic or other enzymatic pathways do not appear to be present in the novel isolate (107), it is inferred this is due to the production of contiguous sequences, since a full genome was not able to created / identified.

1. **Energy Metabolism:** The vast majority of enzymatic pathways for glycolysis / gluconeogenesis had the same conservation between the contiguous sequences of novel isolate 107 and that of the whole genome for the closely related genome of *Flavobacterium plurextorum*. Table one visualizes the overarching similarities between the contigs and the reference genome. Figure one shows the metabolic map describing this relationship as well. The major differences occur between pyruvate metabolism and starch / sucrose metabolism of the novel isolate 107 contigs and reference genome of *Flavobacterium plurextorum*, where 29.7% of genes for pyruvate metabolism and 25.4% starch and sucrose metabolism are from the reference genome, and 31.2 % and 26.8% make up the pyruvate and starch / sucrose metabolism respectively for novel isolate 107. Novel isolate 107 has a Sucrose-6-phosphate hydrolase not found in *Flavobacterium plurextorum*, which likely accounts for the positive difference in distinct ECs for starch and sucrose metabolism. It also contains Alpha-N-acetylglucosaminidase, a Predicted transcriptional regulator of N-Acetylglucosamine utilization (GntR family), Alpha-glucosidase, D-mannonate oxidoreductase, and a Hypothetical glycoside hydrolase, family 43, similar to arabinosidase that *Flavobacterium plurextorum* does not have as well.

Table 1: Shows an image detailing the conservation percentage of each KEGG Map division for glycolysis / gluconeogenesis.

KEGG map	Distinct ECs	Flavobacterium plurextorum	Flavobacterium Unicycler107	Flavobacterium shovill107
Carbon fixation in photosynthetic organisms	25	14 (56.0 %)	14 (56.0 %)	14 (56.0 %)
Citrate cycle (TCA cycle)	22	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)
Glycolysis / Gluconeogenesis	41	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)
Pentose phosphate pathway	37	17 (45.9 %)	18 (48.6 %)	18 (48.6 %)
Propanoate metabolism	47	9 (19.1 %)	9 (19.1 %)	9 (19.1 %)
Pyruvate metabolism	64	19 (29.7 %)	20 (31.2 %)	20 (31.2 %)
Starch and sucrose metabolism	71	18 (25.4 %)	19 (26.8 %)	19 (26.8 %)

Figure 2: Demonstrates the flowchart / enzymatic pathways for glycolysis / gluconeogenesis.



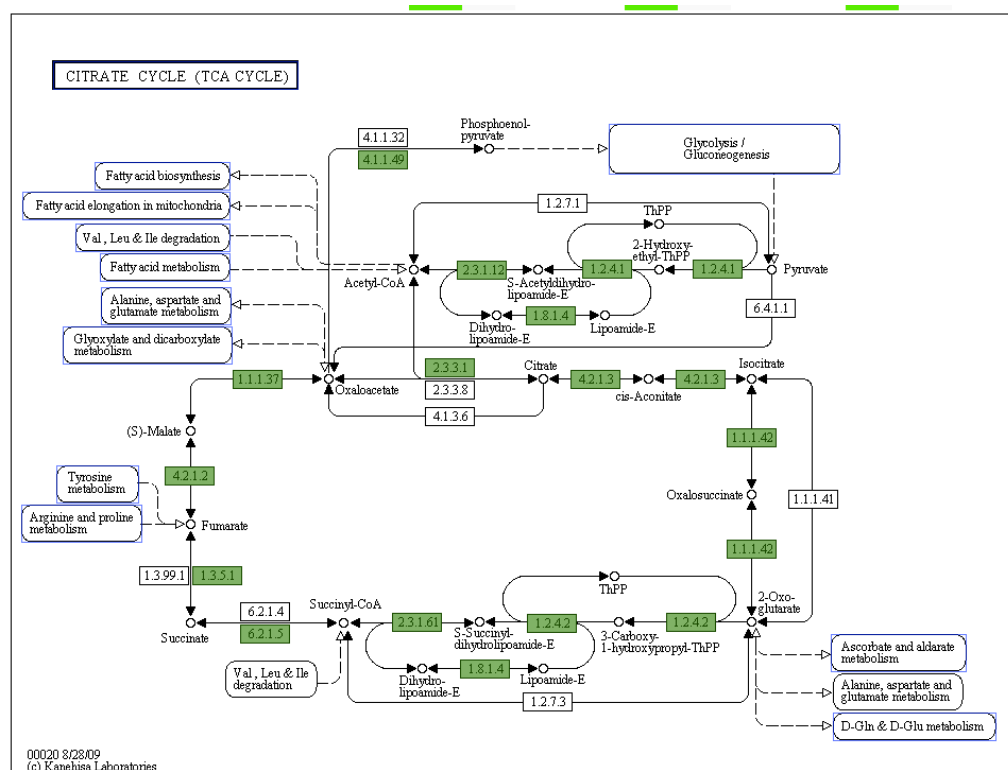
There is a high level of conservation between *Flavobacterium plurectorum* and novel isolate regarding the Citrate / TCA Cycle as well. The two major differences is that the reference genome has a higher percentage of Ascorbate and aldarate metabolism at 18.2% compared to 15.9% for the same metabolism found in the novel isolate contigs, the other being a higher percentage of glyoxylate and dicarboxylate metabolism in the novel isolate 107 contigs (20.7% versus 19.0 %) found in *Flavobacterium plurectorum*. There is also a lower percentage of genes relating to Tyrosine metabolism in the novel isolate 107 contigs at 14.3% compared to the 17.5% of metabolic genes related to Tyrosine metabolism in the Citrate / TCA cycle of *F. plurectorum*. Novel isolate 107 lacks Endo- α -mannosidase, low-specificity D-threonine

aldolase, NAD-specific glutamate dehydrogenase, Glutaminase, Arginine/ornithine antiporter ArcD, Ornithine cyclodeaminase, Aromatic-L-amino-acid decarboxylase, 1-pyrroline-4-hydroxy-2-carboxylate deaminase, 4-hydroxyproline epimerase, Proline iminopeptidase, and Cytosine deaminase.

Table 2: Shows an image detailing the conservation percentage of each KEGG Map division for Citrate / TCA Cycle.

KEGG map	Distinct ECs	Flavobacterium plurectorum	Flavobacterium Unicycler107	Flavobacterium shovill107
Alanine, aspartate and glutamate metabolism	43	20 (46.5 %)	18 (41.9 %)	18 (41.9 %)
Arginine and proline metabolism	97	26 (26.8 %)	18 (18.6 %)	18 (18.6 %)
Ascorbate and aldarate metabolism	44	8 (18.2 %)	7 (15.9 %)	7 (15.9 %)
Citrate cycle (TCA cycle)	22	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)
D-Glutamine and D-glutamate metabolism	13	4 (30.8 %)	3 (23.1 %)	3 (23.1 %)
Fatty acid biosynthesis	21	11 (52.4 %)	11 (52.4 %)	11 (52.4 %)
Fatty acid elongation in mitochondria	8	3 (37.5 %)	3 (37.5 %)	3 (37.5 %)
Fatty acid metabolism	29	8 (27.6 %)	8 (27.6 %)	8 (27.6 %)
Glycolysis / Gluconeogenesis	41	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)
Glyoxylate and dicarboxylate metabolism	58	11 (19.0 %)	12 (20.7 %)	12 (20.7 %)
Tyrosine metabolism	63	11 (17.5 %)	9 (14.3 %)	9 (14.3 %)
Valine, leucine and isoleucine degradation	34	17 (50.0 %)	17 (50.0 %)	17 (50.0 %)

Figure 2: Demonstrates the flowchart / enzymatic pathways for the Citrate Cycle / TCA Cycle.



Novel isolate 107 and *Flavobacterium plurectorum* also share Phosphoribosylanthranilate isomerase, 3-hydroxyanthranilate 3,4-dioxygenase, Kynureninase, Kynurenine 3-monooxygenase, NAD kinase, NAD synthetase, Nicotinate-nucleotide adenyltransferase, Quinolinate phosphoribosyltransferase

[decarboxylating], Ribosyl nicotinamide transporter (PnuC-like), Tryptophan 2,3-dioxygenase, 3,4-dihydroxy-2-butanone 4-phosphate synthase, 5-amino-6-(5-phosphoribosylamino)uracil reductase, 6,7-dimethyl-8-ribityllumazine synthase, Diaminohydroxyphosphoribosylaminopyrimidine deaminase, FMN adenylyltransferase, GTP cyclohydrolase II, Riboflavin kinase, Riboflavin synthase eubacterial/eukaryotic, 3,4-dihydroxy-2-butanone 4-phosphate synthase, FMN adenylyltransferase, Riboflavin kinase, and Riboflavin synthase eubacterial/eukaryotic. Novel isolate 107 is lacking Nicotinamide-nucleotide adenylyltransferase (NadR family), Ribosyl nicotinamide kinase, Cytochrome c-type biogenesis protein DsbD, protein-disulfide reductase, Putative cytochrome C-type biogenesis protein, Type cbb3 cytochrome oxidase biogenesis protein CcoG, involved in Cu oxidation, Type cbb3 cytochrome oxidase biogenesis protein CcoI, Type cbb3 cytochrome oxidase biogenesis protein CcoS (involved in heme b insertion), Heme A synthase, cytochrome oxidase biogenesis protein Cox15-CtaA, Quinone oxidoreductase, Cytochrome c551/c552, Cytochrome c552, Ferredoxin, Ferredoxin, 2Fe-2S, NADH ubiquinone oxidoreductase chains A through N, ATP synthase F0 sector subunit a, ATP synthase F0 sector subunit b, ATP synthase F0 sector subunit c, ATP synthase alpha chain, ATP synthase beta chain, ATP synthase delta chain, ATP synthase epsilon chain, ATP synthase gamma chain, and ATP synthase protein I.

2. The Central Dogma: Genes relating to the central dogma, such as DNA replication and maintenance, as well as transcription factors, RNA synthesis and polymerases, as well as tRNA factors for protein production appear to be equally present between novel isolate 107 and *Flacobacterium plurectorum*, the reference genome. Both organisms have DNA polymerase III epsilon subunit, Predicted signal-transduction protein containing cAMP-binding and CBS domains, Ribonuclease HI, DNA recombination and repair protein RecO, DNA-directed RNA polymerase omega subunit, GTP pyrophosphokinase ((p)ppGpp synthetase II), GTP-binding protein Era, Ribonuclease III, Signal peptidase I, MoxR-like ATPase in aerotolerance operon, Transcriptional regulator (PadR family), Ribosome-binding factor A, Translation initiation factor 2, GTP-binding protein Obg, LSU ribosomal protein L21p, LSU ribosomal protein L27p, 16S rRNA (guanine(966)-N(2))-methyltransferase, FIG032012: hypothetical protein, Alanine-tRNA synthetase, FIG032842: Transcriptional regulator, Peptidase, family M23, DNA recombination and repair protein RecF, TPR domain protein, DNA polymerase III epsilon subunit, Ribonuclease HI, 16S rRNA (guanine(966)-N(2))-methyltransferase, Phosphopantetheine adenylyltransferase, 16S rRNA (guanine(966)-N(2))-methyltransferase, Phosphopantetheine adenylyltransferase, Methionine aminopeptidase, SSU ribosomal protein S2p (SAe), Translation elongation factor Ts, RNA polymerase sigma-70 factor, Short form Mg-chelase associated protein with vWA domain, Magnesium chelatase, subunit ChII, Metal-dependent hydrolase YbeY (involved in rRNA and/or ribosome maturation and assembly), DNA gyrase subunit A, DNA gyrase subunit B, Chromosomal replication initiator protein Dna, DNA gyrase subunit A, DNA gyrase subunit B, DNA polymerase III beta subunit, DNA recombination and repair protein RecF, Ribosome-associated heat shock protein implicated in the recycling of the 50S subunit (S4 paralog), Zn-ribbon-containing, possibly RNA-binding protein and truncated derivatives, 4-hydroxythreonine-4-phosphate dehydrogenase, SSU rRNA (adenine(1518)-N(6)/adenine(1519)-N(6))-dimethyltransferase, DNA recombination and repair protein RecO, GTP-binding protein Era, Glycyl-tRNA synthetase, Metal-dependent hydrolase YbeY, involved in rRNA and/or ribosome maturation and assembly, Phosphate starvation-inducible protein PhoH, predicted ATPase, Low molecular weight protein tyrosine phosphatase, Ribosome-binding factor A, Transcription termination protein NusA, Translation initiation factor 2, Exodeoxyribonuclease VII large subunit, Inosine-5'-monophosphate dehydrogenase, Ribosome recycling factor, SSU ribosomal protein S2p (SAe), Translation elongation factor Ts, DEDDh 3'-5' exonuclease domain of the epsilon subunit of DNA polymerase

III, Error-prone repair homolog of DNA polymerase III alpha subunit, DNA topoisomerase I, DNA topoisomerase III, DNA gyrase subunit A, DNA gyrase subunit B, DNA polymerase III subunits gamma and tau, DNA topoisomerase III, Recombination protein RecR, DNA-binding protein HU-beta, Integration host factor alpha/beta, Type I restriction-modification system (restriction subunit R), Peptide chain release factor 2, programmed frameshift-containing SSU ribosomal protein S10p (S20e), SSU ribosomal protein S11p (S14e), SSU ribosomal protein S12p (S23e), SSU ribosomal protein S13p (S18e), SSU ribosomal protein S14p (S29e), SSU ribosomal protein S14p (S29e) (zinc-independent), SSU ribosomal protein S15p (S13e), SSU ribosomal protein S16p, SSU ribosomal protein S17p (S11e), SSU ribosomal protein S18p, SSU ribosomal protein S18p (zinc-independent), SSU ribosomal protein S19p (S15e), SSU ribosomal protein S1p, SSU ribosomal protein S20p, SSU ribosomal protein S21p, SSU ribosomal protein S2p (SAe), SSU ribosomal protein S3p (S3e), SSU ribosomal protein S4p (S9e), SSU ribosomal protein S5p (S2e), SSU ribosomal protein S6p, SSU ribosomal protein S7p (S5e), SSU ribosomal protein S8p (S15Ae), SSU ribosomal protein S9p (S16e), Translation elongation factor G, Translation elongation factor LepA, Translation elongation factor P, Translation elongation factor Ts, Translation elongation factor Tu, Methionyl-tRNA formyltransferase, Ribosome-binding factor A, Translation initiation factor 1, Translation initiation factor 2, Translation initiation factor 3, Translation initiation factor SUI1-related protein, Methionine aminopeptidase, Peptide chain release factor 1, Peptide chain release factor 2, Peptide chain release factor 3, Peptide deformylase, Peptidyl-tRNA hydrolase, Ribosome recycling factor, tmRNA-binding protein SmpB, 5S rRNA, LSU rRNA, SSU rRNA, Alanyl-tRNA synthetase, Arginyl-tRNA synthetase, Asparaginyl-tRNA synthetase, Aspartyl-tRNA synthetase, Cysteinyl-tRNA synthetase, Glutaminyl-tRNA synthetase, Glutamyl-tRNA synthetase, Glycyl-tRNA synthetase, Histidyl-tRNA synthetase, Isoleucyl-tRNA synthetase, Leucyl-tRNA synthetase, Lysyl-tRNA synthetase (class II), Methionyl-tRNA synthetase, Phenylalanyl-tRNA synthetase alpha chain, Phenylalanyl-tRNA synthetase beta chain, Prolyl-tRNA synthetase (archaeal/eukaryal type), Seryl-tRNA synthetase, Threonyl-tRNA synthetase, Tryptophanyl-tRNA synthetase, Tyrosyl-tRNA synthetase, Valyl-tRNA synthetase, Membrane alanine aminopeptidase NXaa-Pro aminopeptidase, Alpha-aspartyl dipeptidase Peptidase E, D-alanyl-D-alanine carboxypeptidase, Muramoyltetrapeptide carboxypeptidase, Aminopeptidase C, Dipeptidyl carboxypeptidase Dcp, Leucyl/phenylalanyl-tRNA--protein transferase, DNA repair protein RadA, Prolyl endopeptidase, FKBP-type peptidyl-prolyl cis-trans isomerase FkpA precursor, Cytochrome c-type biogenesis protein DsbD, protein-disulfide reductase, Chaperone protein DnaJ, Chaperone protein DnaK, Chaperone protein HtpG, DnaJ-class molecular chaperone CbpA, Heat shock protein GrpE, Deoxyhypusine synthase, Translation elongation factor P, Protein-L-isoaspartate O-methyltransferase, Lipoprotein signal peptidase, Signal peptidase I, 16S rRNA (guanine(966)-N(2))-methyltransferase, SSU rRNA (adenine(1518)-N(6)/adenine(1519)-N(6))-dimethyltransferase, tRNA (5-methylaminomethyl, 2-thiouridylate)-methyltransferase, tRNA (cytidine(34)-2'-O)-methyltransferase, tRNA (guanosine(18)-2'-O)-methyltransferase, Exoribonuclease RNase R, Ribonuclease III, Ribonuclease HI, Ribonuclease HII, Cysteine desulfurase, tRNA (5-methylaminomethyl-2-thiouridylate)-methyltransferase, Ribonuclease P protein component, Ribonuclease Z, tRNA dimethylallyltransferase, tRNA(Ile)-lysine synthetase, DNA-directed RNA polymerase alpha subunit, DNA-directed RNA polymerase beta subunit, DNA-directed RNA polymerase beta subunit, DNA-directed RNA polymerase omega subunit, Predicted transcriptional regulator of sulfate adenylyltransferase (Rrf2 family), Predicted transcriptional regulator of sulfate transport (Rrf2 family), Rrf2 family transcriptional regulator (group III), Regulator of nucleoside diphosphate kinase, Transcription accessory protein (S1 RNA-binding domain), Transcription antitermination protein NusG, Transcription elongation factor GreA, Transcription

termination factor Rho, Transcription termination protein NusA, Transcription termination protein NusB, Transcription-repair coupling factor, Transcriptional activator RfaH, RNA polymerase sigma factor RpoD, RNA polymerase sigma-54 factor RpoN, and RNA polymerase sigma-70 factor. Novel isolate 107 also contains Metallo-beta-lactamase family protein, RNA-specific and RNA polymerase sigma factor RpoE not found in *Flavobacterium plurectorum*. Novel isolate 107 also lacks, LSU ribosomal protein L36p, Peptide chain release factor homolog, Aspartyl-tRNA(Asn) amidotransferase subunit A, Glutamyl-tRNA(Gln) amidotransferase subunit A, 4-keto-6-deoxy-N-Acetyl-D-hexosaminy-(Lipid carrier) aminotransferase, Alpha-1,4-N-acetylgalactosamine transferase PglH, Glycosyltransferase PglI, RNA-2',3'-PO4:RNA-5'-OH ligase, Rrf2 family transcriptional regulator and Retron-type RNA-directed DNA polymerase. DNA-binding protein in cluster with Type I restriction-modification system and Type I restriction-modification system and DNA-methyltransferase subunit M are also found exclusively in novel isolate 107 but not the reference genome. DNA topoisomerase III (Bacteroidales-type) and Type III restriction-modification system methylation subunit are found in the reference genome but not in novel isolate 107.

3. Carbon Sources: There are a wide range of genes pertaining to carbon source utilization and metabolism in both the *Flacobacterium plurectorum* as well as in novel isolate 107. Genes found in novel isolate 107 not found in the reference genome include Alpha-N-acetylglucosaminidase, Predicted transcriptional regulator of N-Acetylglucosamine utilization (GntR family), Sucrose-6-phosphate hydrolase, Alpha-glucosidase, D-mannonate oxidoreductase, and a Hypothetical glycoside hydrolase (family 43, similar to arabinosidase). *Flacobacterium plurectorum* has an Endo-alpha-mannosidase gene not found in isolate 107 as well. Other genes conserved between the two organisms relating to carbon source utilization / metabolism include Glucosamine-6-phosphate deaminase, N-acetyl glucosamine transporter (NagP), N-acetylglucosamine related transporter (NagX), N-acetylglucosamine-6-phosphate deacetylase, Predicted N-acetyl-glucosamine kinase 2 (ROK family), 2-oxoglutarate dehydrogenase E1 component, Branched-chain alpha-keto acid dehydrogenase, E1 component (alpha subunit), Branched-chain alpha-keto acid dehydrogenase, E1 component (beta subunit), Dihydrolipoamide acetyltransferase component of pyruvate dehydrogenase complex, Dihydrolipoamide acyltransferase component of branched-chain alpha-keto acid dehydrogenase complex, Dihydrolipoamide dehydrogenase of branched-chain alpha-keto acid dehydrogenase, Dihydrolipoamide succinyltransferase component (E2) of 2-oxoglutarate dehydrogenase complex, Pyruvate dehydrogenase E1 component alpha subunit, Pyruvate dehydrogenase E1 component beta subunit, Phosphoglycolate phosphatase, Aconitate hydratase, Aconitate hydratase 2, Citrate synthase (si), Isocitrate lyase, Malate dehydrogenase, Malate synthase, Aldehyde dehydrogenase, Aldehyde dehydrogenase B, Methylglyoxal synthase, 6-phosphogluconate dehydrogenase, decarboxylating 6-phosphogluconolactonase, Glucose-6-phosphate 1-dehydrogenase, Ribose-phosphate pyrophosphokinase, Ribulose-phosphate 3-epimerase, Transaldolase, Transketolase (C-terminal section), Transketolase (N-terminal section), Alanine dehydrogenase, Alanine racemase, Branched-chain amino acid aminotransferase, L-serine dehydratase (alpha subunit), L-serine dehydratase (beta subunit), NADP-dependent malic enzyme, Phosphoenolpyruvate carboxykinase [ATP], Phosphoenolpyruvate carboxylase, Pyruvate kinase, Acetate kinase, Aldehyde dehydrogenase, Dihydrolipoamide acetyltransferase component of pyruvate dehydrogenase complex, NAD-dependent protein deacetylase of SIR2 family, Phosphate acetyltransferase, Pyruvate dehydrogenase E1 component alpha subunit, Pyruvate dehydrogenase E1 component beta subunit, Transketolase, Aldose 1-epimerase, Galactokinase, Galactose-1-phosphate uridylyltransferase, UDP-glucose 4-epimerase, Acetolactate synthase large subunit, Acetolactate synthase small subunit, 3-hydroxybutyryl-CoA dehydrogenase, Acetyl-CoA acetyltransferase, Electron transfer flavoprotein (alpha subunit), Electron transfer

flavoprotein (beta subunit), 3-hydroxybutyryl-CoA dehydrogenase, Alcohol dehydrogenase, Enoyl-CoA hydratase, NADH-dependent butanol dehydrogenase A, Acetate kinase, D-lactate dehydrogenase, Phosphate acetyltransferase, Ribokinase, Deoxyribose-phosphate aldolase, Purine nucleoside phosphorylase, Putative deoxyribonuclease YjjV, Ribokinase, L-arabinose isomerase, L-ribulose-5-phosphate 4-epimerase, Possible GPH family transporter (for arabinosides), Protein AraJ precursor, Ribulokinase, Alpha-1,2-mannosidase, Beta-mannosidase, Mannose-6-phosphate isomerase, Phosphomannomutase, D-xylose proton-symporter XylE, Xylanase, Xylose isomerase, Xylulose kinase, 5,10-methylenetetrahydrofolate reductase, 5-formyltetrahydrofolate cyclo-ligase, Formyltetrahydrofolate deformylase, Methenyltetrahydrofolate cyclohydrolase, Methylenetetrahydrofolate dehydrogenase (NADP+), Predicted L-lactate dehydrogenase (Fe-S oxidoreductase subunit YkgE), Predicted L-lactate dehydrogenase (Iron-sulfur cluster-binding subunit YkgF), Predicted L-lactate dehydrogenase (hypothetical protein subunit SO1518), 1,4-alpha-glucan (glycogen) branching enzyme (GH-13-type), Alpha-glucosidase, family 31 of glycosyl hydrolases (COG1501), Glucose-1-phosphate adenyltransferase, Glycogen synthase, ADP-glucose transglucosylase, Glycerol kinase, Glycerol uptake facilitator protein, Glycerol-3-phosphate dehydrogenase, Glycerol-3-phosphate dehydrogenase [NAD(P)+], and Glycerophosphoryl diester phosphodiesterase.

4 Amino Acid Metabolism: The two organisms (both novel isolate 107 and *Flavobacterium plurectorum*) share a bulk of genes in common regarding amino acid metabolism. They include Alanine racemase, Branched-chain amino acid aminotransferase, Cysteine desulfurase, 2-amino-3-ketobutyrate coenzyme A ligase, Serine hydroxymethyltransferase, 2-amino-3-ketobutyrate coenzyme A ligase, Aminomethyltransferase (glycine cleavage system T protein), Cystathionine beta-synthase, Cystathionine gamma-lyase, D-3-phosphoglycerate dehydrogenase, Glycine cleavage system H protein, Glycine dehydrogenase [decarboxylating] (glycine cleavage system P protein), L-serine dehydratase, alpha subunit, L-serine dehydratase, beta subunit, Phosphoserine aminotransferase, Phosphoserine phosphatase, Serine hydroxymethyltransferase, Seryl-tRNA synthetase, Aminomethyltransferase (glycine cleavage system T protein), Dihydrolipoamide dehydrogenase, Glycine cleavage system H protein, Glycine dehydrogenase [decarboxylating] (glycine cleavage system P protein), D-3-phosphoglycerate dehydrogenase, Phosphoserine aminotransferase, Phosphoserine phosphatase, Serine hydroxymethyltransferase, 4-hydroxyphenylpyruvate dioxygenase, 5-carboxymethyl-2-oxo-hex-3- ene-1,7-dioate decarboxylase, Aromatic amino acid transport protein AroP, Phenylalanine-4-hydroxylase, Tryptophan 2,3-dioxygenase, Aminodeoxychorismate lyase, Anthranilate phosphoribosyltransferase, Anthranilate synthase, amidotransferase component, Anthranilate synthase, aminase component, Indole-3-glycerol phosphate synthase, Isochorismate synthase, Para-aminobenzoate synthase, amidotransferase component, Para-aminobenzoate synthase, aminase component, Phosphoribosylanthranilate isomerase, Phosphoribosylformimino-5-aminoimidazole carboxamide ribotide isomerase, Tryptophan synthase alpha chain, Tryptophan synthase beta chain, 2-keto-3-deoxy-D-arabino-heptulosonate-7-phosphate synthase I beta, 3-dehydroquinate dehydratase II, 3-dehydroquinate synthase, Chorismate synthase, Shikimate 5-dehydrogenase I alpha, Shikimate kinase I, Biosynthetic Aromatic amino acid aminotransferase alpha Chorismate mutase I, Prephenate and/or arogenate dehydrogenase (unknown specificity), Prephenate dehydratase, Aminodeoxychorismate lyase, Anthranilate phosphoribosyltransferase, Anthranilate synthase, amidotransferase component, Anthranilate synthase, aminase component, Indole-3-glycerol phosphate synthase, Para-aminobenzoate synthase, amidotransferase component, Para-aminobenzoate synthase, aminase component, Phosphoribosylanthranilate isomerase, Tryptophan synthase alpha chain, Tryptophan synthase beta chain, (R)-citramalate synthase, 2-isopropylmalate synthase, 3-isopropylmalate dehydratase large subunit, 3-isopropylmalate dehydratase small subunit, 3-isopropylmalate dehydrogenase,

Acetolactate synthase large subunit, Acetolactate synthase small subunit, Branched-chain amino acid aminotransferase, Dihydroxy-acid dehydratase, Threonine dehydratase biosynthetic, 3-ketoacyl-CoA thiolase, Branched-chain alpha-keto acid dehydrogenase, E1 component, alpha subunit, Branched-chain alpha-keto acid dehydrogenase, E1 component, beta subunit, Branched-chain amino acid aminotransferase, Dihydrolipoamide acyltransferase component of branched-chain alpha-keto acid dehydrogenase complex, Dihydrolipoamide dehydrogenase of branched-chain alpha-keto acid dehydrogenase, Enoyl-CoA hydratase, 2-isopropylmalate synthase, 3-isopropylmalate dehydratase large subunit, 3-isopropylmalate dehydratase small subunit, 3-isopropylmalate dehydrogenase, Branched-chain amino acid aminotransferase, Branched-chain alpha-keto acid dehydrogenase, E1 component, alpha subunit, Branched-chain alpha-keto acid dehydrogenase, E1 component, beta subunit, Branched-chain amino acid aminotransferase, Dihydrolipoamide acyltransferase component of branched-chain alpha-keto acid dehydrogenase complex, Dihydrolipoamide dehydrogenase, Dihydrolipoamide dehydrogenase of branched-chain alpha-keto acid dehydrogenase, Hydroxymethylglutaryl-CoA lyase, Hydroxymethylglutaryl-CoA reductase, Hydroxymethylglutaryl-CoA synthase, Methylcrotonyl-CoA carboxylase carboxyl transferase subunit, Methylglutaconyl-CoA hydratase, Succinyl-CoA:3-ketoacid-coenzyme A transferase subunit A, Succinyl-CoA:3-ketoacid-coenzyme A transferase subunit B, Branched-chain alpha-keto acid dehydrogenase, E1 component, alpha subunit, Branched-chain alpha-keto acid dehydrogenase, E1 component (beta subunit), Branched-chain amino acid aminotransferase, Dihydrolipoamide acyltransferase component of branched-chain alpha-keto acid dehydrogenase complex, Dihydrolipoamide dehydrogenase of branched-chain alpha-keto acid dehydrogenase, Enoyl-CoA hydratase, NADP-specific glutamate dehydrogenase, Asparagine synthetase [glutamine-hydrolyzing], Aspartate aminotransferase, Aspartate ammonia-lyase, Ferredoxin-dependent glutamate synthase, Glutamate racemase, Glutamate synthase [NADPH] large chain, Glutamate synthase [NADPH] small chain, Glutamine synthetase type II (eukaryotic), Glutamine synthetase type III (GlnN), L-asparaginase I (cytoplasmic), NADP-specific glutamate dehydrogenase, Glutamine synthetase type II (eukaryotic), Glutamine synthetase type III (GlnN), Histidinol dehydrogenase, Histidinol-phosphatase, Histidinol-phosphate aminotransferase, Imidazoleglycerol-phosphate dehydratase, Phosphoribosyl-AMP cyclohydrolase, Phosphoribosyl-ATP pyrophosphatase, Phosphoribosylformimino-5-aminoimidazole carboxamide ribotide isomerase, Formiminoglutamase, Histidine ammonia-lyase, Imidazolonepropionase, Urocanate hydratase, Cystathionine beta-synthase, Cystathionine gamma-lyase, Cysteine synthase, Serine acetyltransferase, Sulfate adenylyltransferase subunit 1, Sulfate adenylyltransferase subunit 2, Sulfate permease, 2,3,4,5-tetrahydropyridine-2,6-dicarboxylate N-succinyltransferase, 4-hydroxy-tetrahydrodipicolinate reductase, 4-hydroxy-tetrahydrodipicolinate synthase, Aspartate-semialdehyde dehydrogenase, Aspartokinase, Diaminopimelate decarboxylase, Diaminopimelate epimerase, 2,3,4,5-tetrahydropyridine-2,6-dicarboxylate N-succinyltransferase, 4-hydroxy-tetrahydrodipicolinate reductase, 4-hydroxy-tetrahydrodipicolinate synthase, Aspartate-semialdehyde dehydrogenase, Aspartokinase, Diaminopimelate decarboxylase, Diaminopimelate epimerase, Lysine ketoglutarate reductase, Saccharopine dehydrogenase, 5,10-methylenetetrahydrofolate reductase, 5-methyltetrahydropteroyltriglutamate--homocysteine methyltransferase, Adenosylhomocysteinase, Cystathionine beta-synthase, Cystathionine gamma-lyase, Cysteine synthase, Homoserine O-acetyltransferase, Homoserine dehydrogenase, Homoserine kinase, Methionine ABC transporter ATP-binding protein, Methionine ABC transporter permease protein, Methionine ABC transporter substrate-binding protein, O-acetylhomoserine sulfhydrylase, O-succinylhomoserine sulfhydrylase, S-adenosylmethionine synthetase, Serine acetyltransferase, Aspartate aminotransferase, Aspartate-semialdehyde dehydrogenase, Aspartokinase, Homoserine dehydrogenase, Homoserine kinase, Threonine synthase, L-allo-threonine aldolase, Threonine dehydrogenase and related Zn-dependent dehydrogenases,

Delta-1-pyrroline-5-carboxylate dehydrogenase, Gamma-glutamyl phosphate reductase, Glutamate 5-kinase, NADP-specific glutamate dehydrogenase, Pyrroline-5-carboxylate reductase, 1-pyrroline-4-hydroxy-2-carboxylate deaminase, 4-hydroxyproline epimerase, Proline iminopeptidase, Cytosine deaminase, Chitinase, Glucosamine-6-phosphate deaminase, N-acetyl glucosamine transporter (NagP), N-acetylglucosamine related transporter (NagX), N-acetylglucosamine-6-phosphate deacetylase, Predicted N-acetyl-glucosamine kinase 2 (ROK family), Alpha-N-acetylglucosaminidase, and a Predicted transcriptional regulator of N-Acetylglucosamine utilization (GntR family). Genes not found in novel isolate 107 but found in the reference genome include those for a Arginine/ornithine antiporter ArcD, Ornithine cyclodeaminase, Aromatic-L-amino-acid decarboxylase, NAD-specific glutamate dehydrogenase, Glutaminase, low-specificity D-threonine aldolase, 1-pyrroline-4-hydroxy-2-carboxylate deaminase, 4-hydroxyproline epimerase, Proline iminopeptidase, and Cytosine deaminase. Genes found in novel isolate 107 not found in *Flavobacterium plurectorum* include Isochorismatase, Aspartate racemase, L-asparaginase, Alpha-N-acetylglucosaminidase, and Predicted transcriptional regulator of N-Acetylglucosamine utilization, GntR family

5 Lipid Metabolism: There appears to be maximum overlap between the genome of novel isolate 107 and the reference genome (*Flacobacterium plurectorum*) relating to fatty acids, lipids, and isoprenoids such as 3-hydroxyacyl-[acyl-carrier-protein] dehydratase (FabZ form), 3-oxoacyl-[acyl-carrier-protein] synthase (KASI), Acetyl-coenzyme A carboxyl transferase alpha chain, Acetyl-coenzyme A carboxyl transferase beta chain, Acyl carrier protein, Acyl carrier protein phosphodiesterase, Biotin carboxyl carrier protein of acetyl-CoA carboxylase, Biotin carboxylase of acetyl-CoA carboxylase, Malonyl CoA-acyl carrier protein transacylase, 3-ketoacyl-CoA thiolase, Enoyl-CoA hydratase, Long-chain-fatty-acid--CoA ligase, 1-deoxy-D-xylulose 5-phosphate synthase, Acetyl-CoA acetyltransferase, Diphosphomevalonate decarboxylase, Hydroxymethylglutaryl-CoA reductase, Hydroxymethylglutaryl-CoA synthase, Mevalonate kinase, Phosphomevalonate kinase, Undecaprenyl diphosphate synthase, Geranylgeranyl diphosphate synthase, Hexaprenyl diphosphate synthase (farnesyl-diphosphate specific), Undecaprenyl diphosphate synthase, Diphosphomevalonate decarboxylase, Hydroxymethylglutaryl-CoA reductase, Hydroxymethylglutaryl-CoA synthase, Mevalonate kinase, Phosphomevalonate kinase, and Beta-carotene hydroxylase.

6 Cell Division: Genes commonly associated with cell division seem to be equally distributed between the reference genome *Flacobacterium plurectorum* and novel isolate 107. Genes associated with cell division, such as Cell division protein FtsI [Peptidoglycan synthetase], Intramembrane protease RasP/YluC (implicated in cell division based on FtsL cleavage), Undecaprenyl diphosphate synthase, Rod shape-determining protein MreB, Rod shape-determining protein MreC, Rod shape-determining protein MreD, Rod shape-determining protein RodA, Septum formation protein Maf, Septum site-determining protein MinD, and Septum site-determining protein MinD are all present. Other genes, including Murein Hydrolases, which aid in sputum cleavage and separation are present in both organisms as well. DNA polymerase III epsilon subunit (a major constituent for bacterial cell division is also present), as is Predicted signal-transduction protein containing cAMP-binding and CBS domains and Ribonuclease HI are present each in *Flacobacterium plurectorum* and novel isolate 107.

7 DNA Repair: Novel isolate 107 appears to be missing DNA-cytosine methyltransferase, Endonuclease V, Exodeoxyribonuclease VII small subunit, and Very-short-patch mismatch repair endonuclease (G-T specific) in reference to *Flavobacterium plurectorum*. Novel isolate 107 does contain Phosphoglycolate phosphatase, Excinuclease ABC subunit A, Excinuclease ABC subunit A paralog in greater Bacteroides group, Excinuclease ABC subunit B, Excinuclease ABC subunit C, A/G-specific adenine glycosylase, ADA regulatory protein, DNA polymerase IV, DNA recombination protein RmuC, DNA repair protein

RadADNA repair protein RecN, Exodeoxyribonuclease III, Exodeoxyribonuclease VII large subunit, Methylated-DNA--protein-cysteine methyltransferase, RecA protein, Single-stranded DNA-binding protein, DNA mismatch repair protein MutL, DNA mismatch repair protein MutS, MutS-related protein family 1, Recombination inhibitory protein MutS2, ATP-dependent DNA helicase RecQ, ATP-dependent DNA helicase RecS (RecQ family), DNA recombination and repair protein RecF, DNA recombination and repair protein RecO, RecA protein, Recombination protein RecR, Single-stranded DNA-binding protein, Deoxyribodipyrimidine photolyase, DNA mismatch repair protein MutS, RecA protein, Regulatory protein RecX, RecA protein, and Regulatory protein RecX. These are some of the most prominent components of bacterial DNA repair enzymatic pathways and processes, which the new isolate has conserved within its genome.

8 Carbon Fixation: Novel isolate 107 and the reference genome, *Flavobacterium plurectorum*, have multiple components that are conserved within each organism relating to the Calvin–Benson–Bassham Cycle, which include NAD-dependent glyceraldehyde-3-phosphate dehydrogenase, L-ribulose-5-phosphate 4-epimerase, Ribulose-phosphate 3-epimerase, D-3-phosphoglycerate dehydrogenase, and Alpha-ribazole-5-phosphate phosphatase. Both organisms also share a substantial portion of genes related to the Reverse TCA cycle, which includes Acetate kinase, Aldehyde dehydrogenase, Dihydrolipoamide acetyltransferase component of pyruvate dehydrogenase complex, NAD-dependent protein deacetylase of SIR2 family, Phosphate acetyltransferase, Pyruvate dehydrogenase E1 component alpha subunit, Pyruvate dehydrogenase E1 component beta subunit, Isocitrate lyase, Isocitrate dehydrogenase [NADP], Citrate synthase (si), Lysine ketoglutarate reductase, Succinyl-CoA:3-ketoacid-coenzyme A transferase subunit A, Succinyl-CoA:3-ketoacid-coenzyme A transferase subunit B, 2,3,4,5-tetrahydropyridine-2,6-dicarboxylate N-succinyltransferase, Dihydrolipoamide succinyltransferase component (E2) of 2-oxoglutarate dehydrogenase complex, O-succinylbenzoate synthase, Adenylosuccinate lyase, Adenylosuccinate synthetase, Malate dehydrogenase, Malate synthase, Acetyl-CoA acetyltransferase, acetyl-CoA carboxylase, and Biotin carboxylase of acetyl-CoA carboxylase. In terms of the Hydropropionate pathway, novel isolate 107 and *Flavobacterium plurectorum* share genes such as Acetyl-CoA acetyltransferase, acetyl-CoA carboxylase, Biotin carboxylase of acetyl-CoA carboxylase, Malonyl CoA-acyl carrier protein transacylase, Succinyl-CoA:3-ketoacid-coenzyme A transferase subunit A, Succinyl-CoA:3-ketoacid-coenzyme A transferase subunit B, Appears to be lacking genes relating to Malonyl semialdehyde, 3-Hydroxypropionate, Acrylyl-CoA, Propionyl-CoA, Succinyl-CoA, and Malyl-CoA. For methanogenesis, or one carbon metabolism, both organisms contain 5,10-methylenetetrahydrofolate reductase, 5-formyltetrahydrofolate cyclo-ligase, Formyltetrahydrofolate deformylase, Methenyltetrahydrofolate cyclohydrolase, and Methylenetetrahydrofolate dehydrogenase (NADP+).

9 Photosynthesis: No photosynthetic genes have been identified, besides those for the breakdown of photosynthetic materials. Beta-carotenoid hydroxylase, has been identified in both novel isolate 107 as well is in the reference organism. NAD is typically associated with respiration, as are genes regarding its synthesis, and NADP is often associated with photosynthetic pathways. Both novel isolate 107 and the reference genome *Flavobacterium plurectorum* contain Phosphoribosylanthranilate isomerase, 3-hydroxyanthranilate 3,4-dioxygenase, Kynureninase, Kynurenine 3-monooxygenase, NAD kinase, NAD synthetase, Nicotinate-nucleotide adenylyltransferase, Quinolinate phosphoribosyltransferase [decarboxylating], Ribosyl nicotinamide transporter (PnuC-like), and Tryptophan 2,3-dioxygenase. Novel isolate 107 differs from the genome of *Flavobacterium plurectorum* since it does not contain the genes Nicotinamide-nucleotide adenylyltransferase (NadR family) or Ribosylnicotinamide kinase.

10 Oxygen Utilization: Bacteria part of the *Flavobacterium* genus are either aerobic or facultatively aerobic in nature. Both novel isolate 107 and reference organism *Flavobacterium plurectorum* shared oxygen utilization genes, which include Superoxide dismutase [Cu-Zn] precursor, Superoxide dismutase, Alkyl hydroperoxide reductase subunit C-like protein Ferric uptake regulation protein FUR, and Transcriptional regulator (Crp/Fnr family). Some of the aforementioned proteins deal with anaerobic conditions, but these could be artifacts of previous enzymatic pathways or conserved for other related functions, or act as emergency mechanisms should oxygen quality become reduced.

11 Solute Concentration: Both novel isolate 107 and reference organism *Flavobacterium plurectorum* have Aquaporin Z and Glycerol uptake facilitator protein in terms of osmotic stress and osmotic regulation. Novel isolate also contains Outer membrane protein A precursor which is not found in the reference organism genome. Novel isolate 107 also lacks Glycine betaine ABC transport system (ATP-binding protein OpuAA) and Glycine betaine ABC transport system (permease protein OpuAB) which are both found in the genome for *Flavobacterium plurectorum*.

12 Temperature: Novel isolate 107 and the reference organism (*Flavobacterium plurectorum*) both contain Heat shock protein GrpE and Ribosome-associated heat shock protein implicated in the recycling of the 50S subunit (S4 paralog) which suggests that they are capable of mitigating against spikes in heat.

13 Metals: Novel isolate 107 shares similar metal focused genes with *Flavobacterium plurectorum*. These include, Cysteine desulfurase, Ferredoxin, 2Fe-2S, Iron-sulfur cluster assembly ATPase protein SufC, Iron-sulfur cluster assembly protein SufB, Iron-sulfur cluster assembly protein SufD, PaaD-like protein (DUF59) involved in Fe-S cluster assembly, and a probable iron binding protein from the HesB_IscA_SufA family. Iron sulfur clusters are often associated with pathways of photosynthesis, but these may be conserved systems that perform different roles for novel isolate 107 and *Flavobacterium plurectorum*, such as functioning as intermediates for electron transport in cellular respiratory pathways. Novel isolate 107 does not contain Azurin like *Flavobacterium plurectorum* does, which is responsible for redox reactions of copper-containing proteins. Novel isolate 107 contains Beta-galactosidase and Neuraminidase NanP related to sulfur metabolism not found in *Flavobacterium plurectorum*.

14 Resistance to Pollutants: Genes relating to a prokaryotic organism's stress response can be linked to pollutant resistance / tolerance in environments, since pollutants are sources of environmental stress on a cellular system. Novel isolate 107 and reference organism *Flavobacterium plurectorum* have many genes in common, such as Organic solvent tolerance protein precursor, DedA protein, Aquaporin Z, Glycerol uptake facilitator protein, Glutathione peroxidase, Alkyl hydroperoxide reductase subunit C-like protein, Ferric uptake regulation protein FUR, Superoxide dismutase ([Cu-Zn] precursor), Superoxide dismutase ([Mn]), Transcriptional regulator (Crp/Fnr family), Alkyl hydroperoxide reductase subunit (C-like protein), Rubredoxin, Intramembrane protease RasP/YluC (implicated in cell division based on FtsL cleavage), Outer membrane protein H precursor, NG,NG-dimethylarginine dimethylaminohydrolase 1, and Ornithine aminotransferase. Novel isolate 107 does not have Glycine betaine ABC transport system (ATP-binding protein OpuAA), Putative N-acetylgalactosaminyl-diphosphoundecaprenol glucuronosyltransferase, and Glycine betaine ABC transport system (permease protein OpuAB) found in *Flavobacterium plurectorum*. Novel isolate also contains Outer membrane protein A precursor and Lactoylglutathione lyase not found in the reference organism *Flavobacterium plurectorum*.

15 Radiation: The RecA protein has been identified in novel isolate 107 as well as in the reference genome for *Flavobacterium plurectorum*. This would suggest that novel isolate 107 likely has the ability to protect its genome from UV exposure, as is common with the RecA proteins of many prokaryotic

organisms. Novel isolate 107 does not appear to have any other genes specifically relating to radiation tolerance / resistance. Please refer to DNA repair for further understanding of the enzymatic properties relating to that process. MutL and MutS systems have been identified for both novel isolate 107 as well as with *Flavobacterium plurectorum*, the reference organism, but no Lex genes were found in either organism. MutL and MutS complexes are responsible for mismatch repair, so it is inferred that they would likely be important in terms of protection / remediation of radiation damage.

16 Other Abilities: Compared to conventional *Flavobacterium* species, many of which are considered opportunistic pathogens with high levels of antibiotic resistance, including the reference organism of *Flavobacterium plurectorum*, novel isolate 107 does not confer many antibiotic resistance genes. This is potentially influenced by the isolation of novel isolate 107 as a dermal sample from amphibian skin in Grand Teton National Park rather than being isolated from soil or aquiculture samples specifically. Genes not found in the contiguous sequences for novel isolate 107 found in the reference organism *Flavobacterium plurectorum* include Beta-lactamase, Antibiotic biosynthesis monooxygenase, Cation efflux system protein CusA, Cobalt-zinc-cadmium resistance protein CzcA, Cu(I)-responsive transcriptional regulator, Copper homeostasis protein CutF precursor, and FAD-dependent NAD(P)-disulphide oxidoreductase. Novel isolate 107 also lacks a large quantity of transposon proteins, such as Conjugative transposon protein TraA, TraB, TraD, TraG, TraI, TraJ, TraK, TraM, TraO and TraQ compared to *Flavobacterium plurectorum*. Novel isolate 107 also lacks Nitrite reductase accessory protein NirV, Nitrous oxide reductase maturation protein NosD, Nitrous oxide reductase maturation protein NosF (ATPase), Nitrous oxide reductase maturation transmembrane protein NosY, and Nitrous-oxide reductase which are all found in *Flavobacterium plurectorum*.

Genomic Annotation and Comparison of *Flavobacterium plurextorum* and Two Assemblies of a Similar Novel Isolate

Katelynn Miller

December 16th, 2022

Dr. Peter Sheridan

Prokaryotic Genome Annotation – Biology 6670

Energy Metabolism

First, it is important to determine whether the novel isolate has functioning energy metabolism pathways. Table 1 in the supplementary information was used to conclude on whether there was a functioning pathway. First, as can be seen in table 1, all necessary enzymes for Glycolysis and Gluconeogenesis. All the enzymes for the Pentose Phosphate Pathway are also present. However, the enzymes 2-dehydro-3-deoxygluconokinase (EC 2.7.1.45) and 2-dehydro-3-deoxyphosphogluconate aldolase (EC 4.1.2.14) did not match that of *Flavobacterium plurextorum* as well. This is most likely because they are potentially different organisms. The Pyruvate Dehydrogenase complex is mostly accounted for, minus the seemingly absent dihydrolipoyl dehydrogenase complex. Other than this complex, it was determined that the Pyruvate Dehydrogenase complex was likely present and operational, and that the absence of the gene sequence was due to the genome being incomplete. The novel isolate also had an operational Citric Acid Cycle. There also seemed to be an operational Reductive Citric Acid Cycle (Reductive CAC) which is of interest due to the implications that the organism can fix CO₂. It was also concluded from table 1 and the supplementary file entitled “Contig Comparison”, the organism also has a complete Electron transport system and ATP synthase complex. Table 1 shows that there are enzymes for the synthesis of the NAD/NADP/NMN and FAD/FMN electron transporters. Lastly, genes necessary for photosynthesis were determined to be absent. Many of the enzymes necessary for photosynthesis were present. However, it was determined that many of these enzymes came from other biochemical pathways such as Glycolysis and the Pentose Phosphate Pathway. Also, the gene sequence encoding for the enzyme RuBisCo were not found, meaning that photosynthesis was likely impossible for this organism. From this analysis, it was determined that the novel isolate contained all the energy metabolic pathways needed for life (except for photosynthesis). It was also determined that the energy metabolism done by the novel isolate very closely matched that of the comparison organism *F. plurextorum*. This conclusion came to the percent identity match contained in the supplementary “Contig Comparison” document.

The Central Dogma

To determine the functionality of the Central Dogma pathways, Table 2 was used. From this table, it was determined that the organism had a functioning purine and pyrimidine biosynthesis pathways. Also, all components for DNA replication were present, including RNA Polymerases I, III, IV, DNA primase, DNA gyrase, DNA topoisomerase, and DNA ligase. There were also several proteins for DNA excision and repair. Genes for RNA synthesis and degradation were also present. This included all of the necessary subunits of RNA polymerase as well as ribonucleases for RNA degradation. All components necessary for transcription

and translation, including all ribosomal proteins and many transcription factors, were present. Lastly, amino acyl tRNA synthetases for all common 20 amino acids were present. There were no tRNA synthetases for non-canonical amino acids. While analyzing the central dogma pathways, two enzymes of interest were found. The first of these was the “Ribosome-associated heat shock protein implicated in the recycling of the 50S subunit (S4 paralog).” This enzyme was present in both the isolate and in *F. plurextorum* and was interesting because it is associated with stress response to heat shock. The other enzyme of interest was the RNA polymerase sigma factor RpoE because it was only found in the isolate genome. This enzyme is also associated with heat shock and cold shock resistance. An organism without this enzyme will not be heat shock resistant. Thus, RpoE may give the isolate an advantage in higher temperature environments that *F. plurextorum* does not have.

Carbon Sources

To figure out what these organisms use as carbon sources, Table 3 was used. However, it was first determined that one source of carbon for both organisms was CO₂ which is fixed by the Reductive CAC cycle. The organism also has all enzymes required for the Glyoxylate cycle. Other carbon sources for both the isolate and *F. plurextorum* was starch, chitin, N-acetylglucosamine, and protein breakdown. Sugars that the organism then used in many of its pathways included Lactose, Galactose, Sucrose, D-Ribose, L-arabinose, Mannose, and Xylose. Carbon from environmental proteins is possible due to the presence of proteases and peptidases. This was based off the fact that Flavobacteria are sometimes proteolytic. Also, starch and chitin breakdown was apparent due to the presence of amylase and chitinase. Thus, it was concluded that some carbon comes from CO₂ fixation but that most of it comes from the breakdown of large biomolecules such as starch, chitin, and proteins.

Amino Acid Metabolism

Table 4 was used to make conclusions on the presence or absence of amino acid synthesis/degradation. From table 4, it was determined that both the novel isolate and *F. plurextorum* contained metabolic processes for all 20 common amino acids. However, some amino acids only had degradation pathways where other amino acids only had synthetic pathways. Synthetic enzymes for Valine, Arginine, and Isoleucine could not be found. This could partially be due to the incomplete genome used in analysis. Valine, Arginine, and Isoleucine may also be present without designated synthetic enzymes because the organism seems to be proteolytic. This means that the amino acids may come from the breakdown of other proteins. It is also important to mention that the only genes regarding Arginine are degradation

enzymes and enzymes that methylate Arginine. The remaining Amino Acids seemed to have designated synthesis, and general degradation pathways. Thus, it can be concluded that both the novel isolate and *F. plurextorum* utilizes all twenty common amino acids. However, it is important to note that there were three enzymes contained by the novel isolate but were not found in *F. plurextorum*. These enzymes are Aspartate racemase (EC 5.1.1.13) (aspartate biosynthesis), L-asparaginase (EC 3.5.1.1) (asparagine biosynthesis), and Isochorismatase (EC 3.3.2.1) (tryptophan biosynthesis from chorismate). It is unclear whether these enzymes provide the isolate any advantages over *F. plurextorum*.

Lipid Metabolism

Table 5 lists all the enzymes associated with Lipid Metabolism that were found. First, it was determined that all enzymes needed for lipid biosynthesis and degradation are present. There was not a specific enzyme called Fatty Acid Synthase present. It was found that both organisms undergo the bacterial FAS II fatty acid synthesis pathway. This pathway involves FabB, FabF, FabH, FabG, and FabI as well as many of the enzymes present under the “Fatty Acid Biosynthesis” header in Table 5. The necessary components for Acetyl CoA Carboxylase (Biotin carboxylase of acetyl-CoA carboxylase (EC 6.3.4.14) and Biotin carboxyl carrier) were present. All enzymes in the pathway for Geranyl and Farnesyl synthesis were also found and put in Table 5. Lastly, there was a functional Hydroxymethylglutaryl-CoA reductase (EC 1.1.1.34) enzyme. With all of these enzymes present in both the isolate and *F. plurextorum*, it was determined that these organisms have functioning Lipid Metabolism pathways.

Cell Division

Both the isolate and *F. plurextorum* have multiple Fts proteins to aid in cell division. Also present was Mre genes which code for a rod-shaped bacterium as well as RodA, MinD, and Maf which are associated with cell division. There was one protein of interest which was the “intramembrane protease RasP/YluC, implicated in cell division based on FtsL cleavage”. This enzyme’s gene sequence was determined from an isolate near hydrothermal vents. Also, this enzyme seems to function both as a cell division enzyme as well as a stress response protein. This enzyme may work as a stress response protein by cleaving anti-sigma factors. A full list of cell division proteins present can be found in Table 6 in the document entitled “Tables for Pathways” document.

DNA Repair

The isolate has many of the required DNA repair systems including DNA polymerase IV, Mismatch repair (Mut) systems, RecA (and other Rec systems), base/nucleotide excision repair, and the photolyase Deoxyribodipyrimidine photolyase (EC 4.1.99.3). There are not any enzymes or proteins that look unusual for either the isolate or for *F. plurextorum*. Table 7 contains a full list of all the DNA repair systems that were present. Therefore, it can be concluded that there is an operational DNA repair system in place.

Carbon Fixation

Looking again at Table 1, it can be seen that the organism has the Reverse TCA cycle (Reductive CAC) for carbon fixation. This can be concluded by the fact that the enzyme Alanine dehydrogenase (EC 1.4.1.1) does not appear to be present in another common energy pathway except for the Reductive CAC cycle. Because the organism had many of the other necessary enzymes, it was concluded that the isolate does carbon fixation by the reductive CAC cycle. However, the isolate does not appear to have any of the common enzymes for the CCB cycle, Methanogenesis, or the Hydroxy propionate pathway. This was determined by the absence of RuBisCo, methyl-coenzyme M reductase (for methanogenesis), Acetyl-CoA carboxylase (for the Hydroxy propionate pathway), and propionyl-CoA carboxylase (also for Hydroxy propionate pathway). The lack of these essential enzymes was used as an indicator of whether the pathways were present or not.

Photosynthesis

Table 1 contains the EC numbers for all the enzymes originally thought to be a part of photosynthesis. However, after analyzing the identities of these enzymes, it was determined that the organism does not have the ability to do photosynthesis. This is evidenced by the complete lack of photosystems I and II, accessory pigments, and RuBisCo. Although many of the enzymes required for the Calvin-Benson Basham cycle were present, it was determined that many of these enzymes were instead apart of other biochemical pathways such as Glycolysis and the Pentose Phosphate Pathway. Also, because RuBisCo was not found, it was determined that photosynthesis (the CBB cycle) would be impossible. Thus, it was concluded that the isolate nor *F. plurextorum* cannot do photosynthesis.

Oxygen Utilization

By looking at both table 1 and table 8, it was determined that both the isolate and *F. plurextorum* are facultative anaerobes. Both organisms contain the citric acid cycle and other aerobic pathways. However, as evidenced in Table 8, the organism has the anaerobic enzyme “flavodoxin reductases (ferredoxin-NADPH reductases) family 1.” Also, there is a fermentation pathway for lactate, meaning that the organism has the capability of doing anaerobic fermentation in the absence of oxygen. Lastly, both organisms contain the enzyme superoxide dismutase. However, only the isolate has the gene sequence for Catalase-peroxidase KatG (EC 1.11.1.21) which aids in the breakdown of hydrogen peroxide in the cell. Therefore, both organisms were said to have both aerobic and anaerobic capabilities.

Solute Concentration

Table 9 summarizes the osmoregulatory proteins found in the organism. These proteins included OsmC and Ohr family proteins, Aquaporin Z, and proteins for the uptake of osmolytes. It is important to note that the “glycine betaine ABC transport system, ATP-binding protein OpuAA (EC 3.6.3.32)” was only present in the genome for *F. plurextorum*. However, this may just be because the isolate has an incomplete genome. Glycine betaine is a common osmolyte for the adjustment of the concentration of nitrogen compounds. Proteins associated with potassium homeostasis were observed. However, no proteins for pH stress were recognized.

Temperature

After looking through the “Contig Comparison,” “Plurextorum vs Shovil – functional analysis,” and “Plurextorum vs Unicycler - functional analysis” supplementary documents, it was determined that there was some evidence that the organism has genes to deal with temperature extremes. Table 10 has a summary of all heat and cold response enzymes found. The enzymes of interest with a presence in both organisms were the GrpE heat shock protein, GroES chaperone, and GroEL chaperones. The GrpE prevents the buildup of unfolded proteins under high temperatures where the chaperones aid in refolding of the proteins. A gene for a cold shock protein was detected in both organisms. An enzyme that was only present in the isolate was the RNA polymerase sigma factor RpoE enzyme. This enzyme helps with both heat and cold responses, meaning that it may provide an advantage to the isolate that *F. plurextorum* does not have. A comparative experiment may need to be run to determine whether this enzyme causes for an advantage in the isolate.

Metals

Both organisms use a variety of metals for electron transport and catalysis. They also have detoxification and metal regulation pathways present. Table 11 summarizes the enzymes having to do with metals. First, it is important to note that Iron is used for many different applications. The most common applications are for Iron-sulfur clusters, ferredoxin, and ferrochelatase which incorporates iron into a porphyrin ring. Other metals such as magnesium and copper are also seen incorporated into a porphyrin for electron transport. Azurin, which utilizes copper and functions as electron transport, was also present. Lastly, there were enzymes for the regulation and removal of Hg, Cr, Co, Cu, and Cd. There were some of the metal resistance genes that were only present in *F. plurextorum*. However, it is likely that these were absent due to the isolate genomes being incomplete.

Resistance to Pollutants

Table 11 shows the genes associated with pollutants and antibiotics. Both organisms were found to have antibiotic resistance. This was evidenced by the presence of β -lactamase, and a fluoroquinolone resistant DNA gyrase. Both organisms also have genes to detoxify from the presence of nucleoside triphosphate pyrophosphatases which are used in enzymatic household cleaners. This enzyme works to hydrolyze the pyrophosphate into its component monophosphates resulting in a halt in protein synthesis.

Radiation

After looking through the “Contig Comparison,” “Plurextorum vs Shovil – functional analysis,” and “Plurextorum vs Unicycler - functional analysis” supplementary documents, it was determined that there was no evidence supporting radiation resistance. The only “radiation resistance” that could be noted was from the enzyme Deoxyribodipyrimidine photolyase (EC 4.1.99.3) which aids in the repair of DNA damage from UV radiation.

Other Abilities

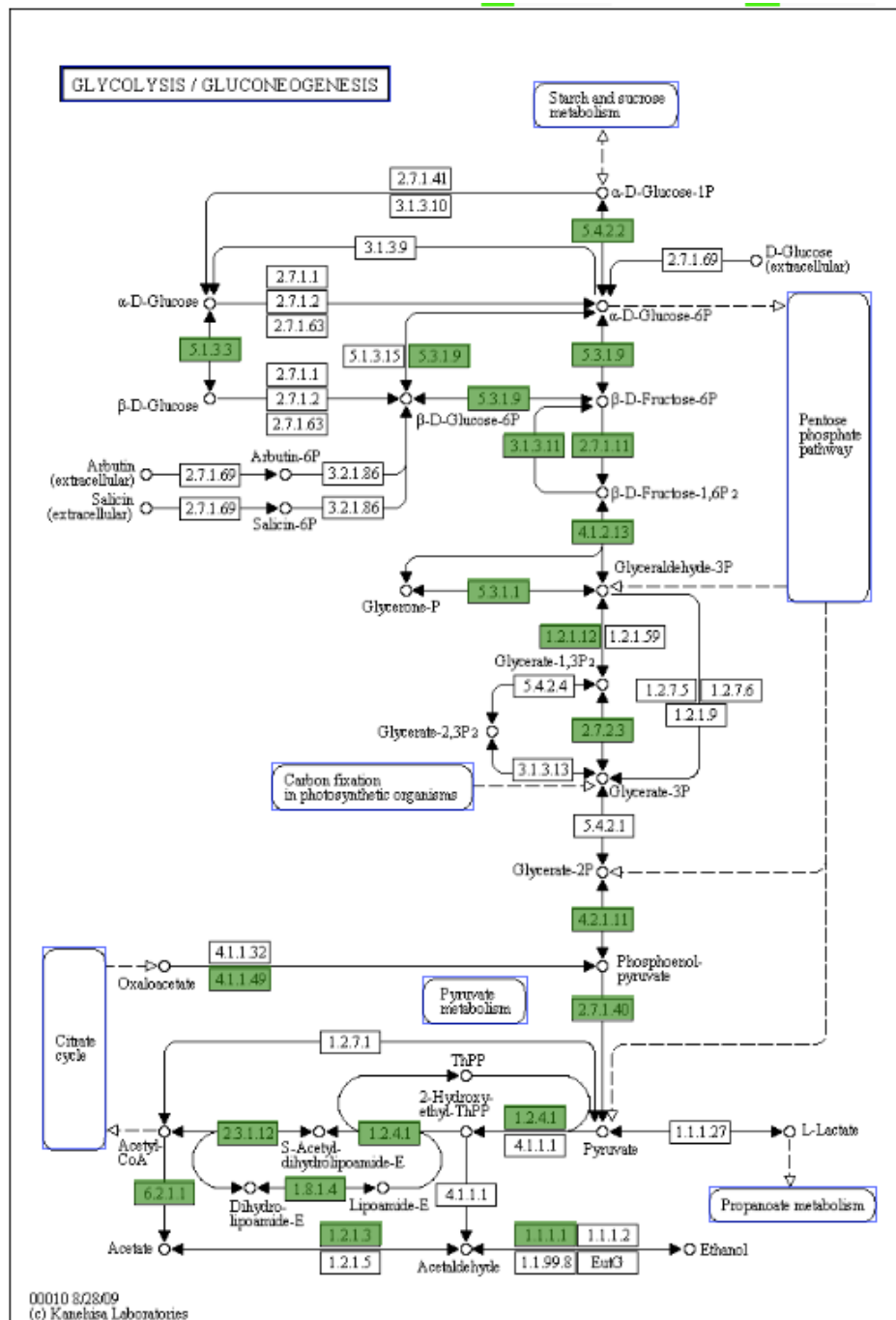
Table 12 was used to conclude what other abilities that the isolate and *F. plurextorum* contain. It was seen that both organisms have some enzymes associated with sulfur metabolism. However, only Arylsulfatase (EC 3.1.6.1) seemed to have a function related to the sulfur cycle. This enzyme works to break down biomolecules containing sulfur and converting it to a sulfate. The other enzymes seem to pertain to the

Fe-S clusters and the breakdown of reactive oxygen species. From Table 12, it was also seen that neither organism is capable of nitrogen fixation due to the absence of *nif* genes proteins. Only *F. plurextorum* had all of the necessary enzymes for denitrification. However, the isolate did have a nitrite reductase enzyme which would allow it to convert NO_2^- to NO . Both organisms are also capable of ammonification, which is the conversion of nitrogen containing compounds and converting it into NH_3 or NH_4^+ . Neither *F. plurextorum* nor the isolate seemed to be capable of nitrification. Both organisms also can do phosphate metabolism. Most of the enzymes found for phosphate metabolism have to do with the breakdown of polyphosphates from biomolecules. There were also several enzymes for the transport of inorganic phosphate. There were no specific enzymes observed for the maintenance of pH level.

Other special abilities contained by one or both organisms are listed in table 12. Only the isolate contained a protein entitled “Phage capsid proteins” which is the protein capsid of an unknown bacteriophage. However, this did not provide insight into the organism’s abilities. There were other transposon proteins only found in the *F. plurextorum* genome. There did not appear to be genes for RISC, Dicer, or CRISPR. However, it was found that *F. plurextorum* may have a capability to form biofilms as evidenced by the presence of a “minor curlin subunit CsgB” enzyme. This enzyme may be found on a more complete genome for the isolate. Both organisms were found to have antibiotic resistance. This was evidenced by the presence of β -lactamase, and a fluoroquinolone resistant DNA gyrase.

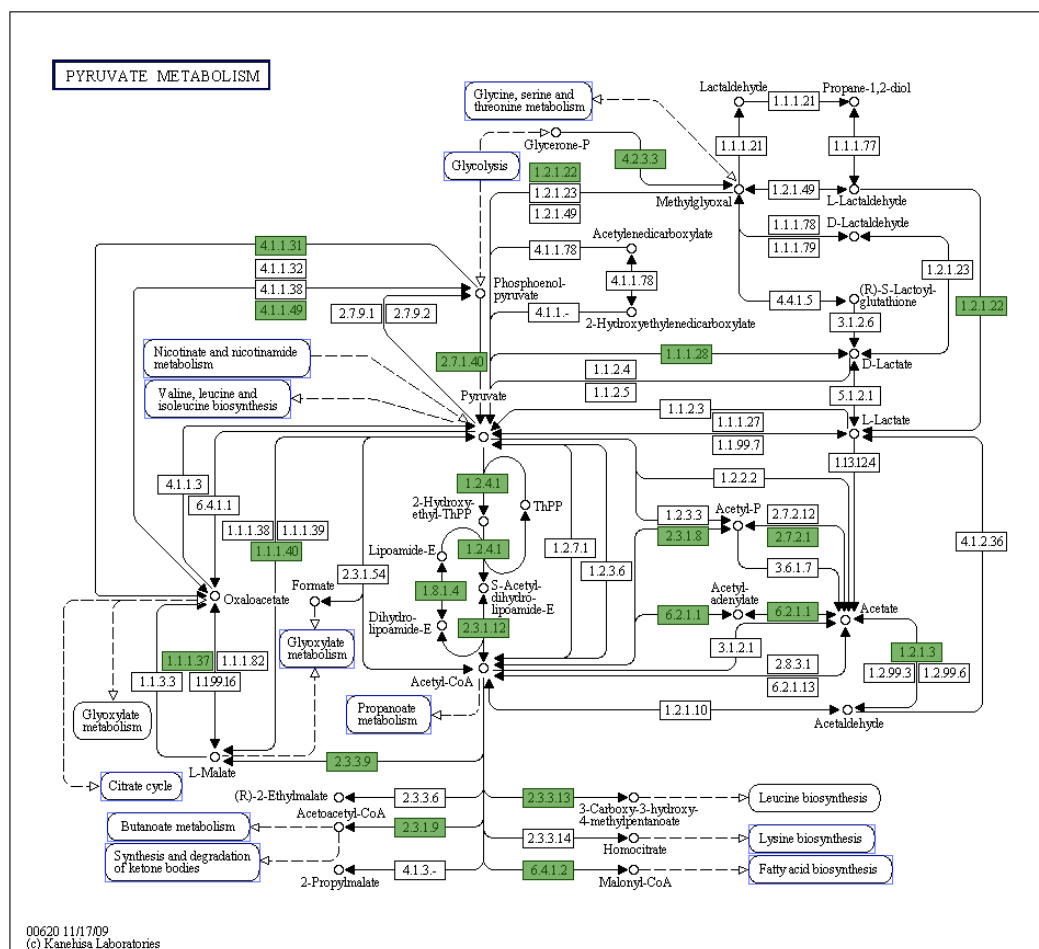
Glycolysis/Gluconeogenesis

KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicycler
Carbon fixation in photosynthetic organisms	25	14 (56.0 %)	14 (56.0 %)	14 (56.0 %)
Citrate cycle (TCA cycle)	22	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)
Glycolysis / Gluconeogenesis	41	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)
Pentose phosphate pathway	37	17 (45.9 %)	18 (48.6 %)	18 (48.6 %)
Propanoate metabolism	47	9 (19.1 %)	9 (19.1 %)	9 (19.1 %)
Pyruvate metabolism	64	19 (29.7 %)	20 (31.2 %)	20 (31.2 %)
Starch and sucrose metabolism	71	18 (25.4 %)	19 (26.8 %)	19 (26.8 %)



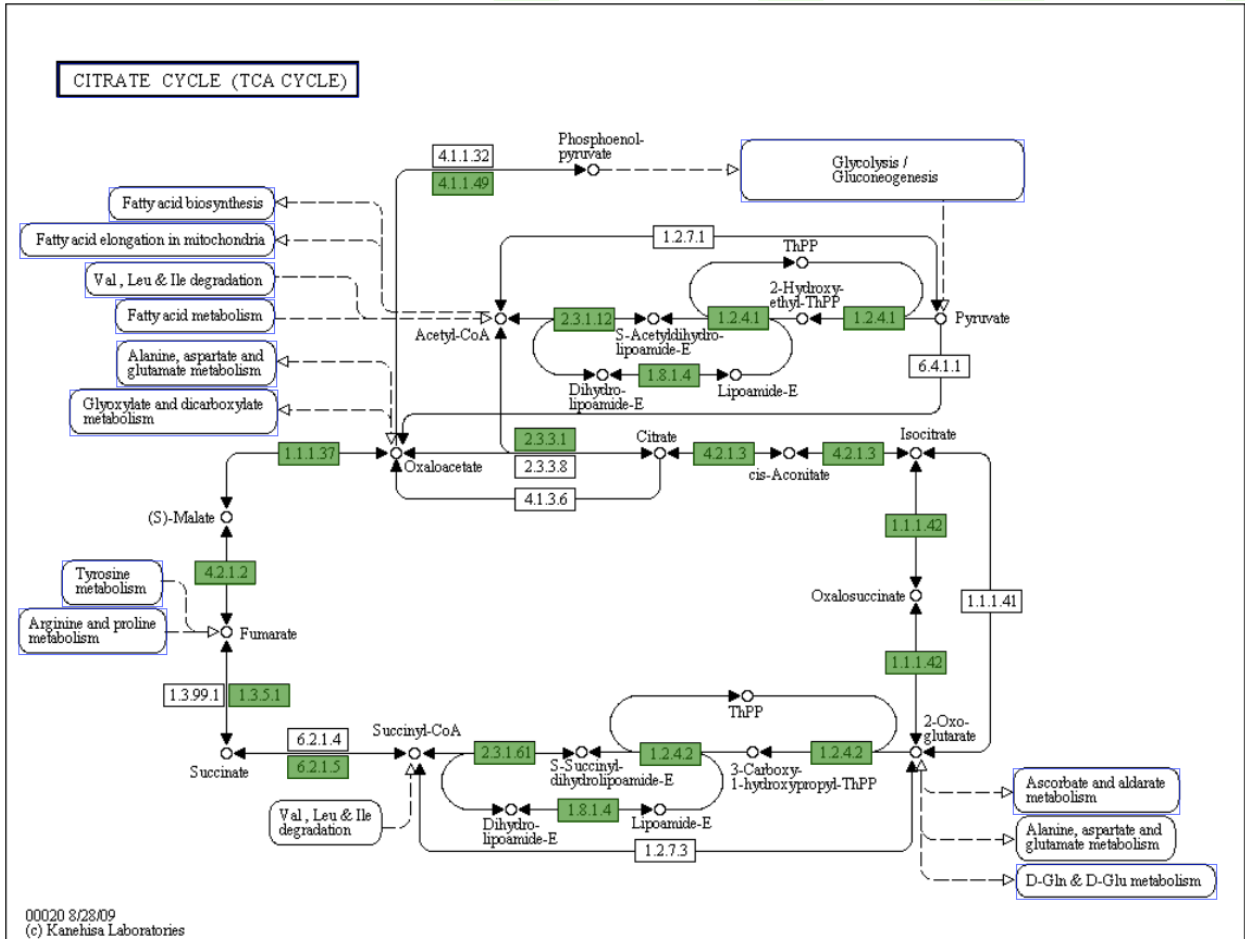
KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicyler	Unknown sp. 107unicyler
	0	0	0	0	0
Glycolysis / Gluconeogenesis	41	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)
Histidine metabolism	37	16 (43.2 %)	15 (40.5 %)	15 (40.5 %)	15 (40.5 %)
Pentose and glucuronate interconversions	56	22 (39.3 %)	22 (39.3 %)	22 (39.3 %)	22 (39.3 %)
Pentose phosphate pathway	37	17 (45.9 %)	18 (48.6 %)	18 (48.6 %)	18 (48.6 %)
Purine metabolism	104	42 (40.4 %)	39 (37.5 %)	39 (37.5 %)	39 (37.5 %)
Pyrimidine metabolism	64	26 (40.6 %)	24 (37.5 %)	24 (37.5 %)	24 (37.5 %)

KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicycler
Butanoate metabolism	52	12 (23.1 %)	12 (23.1 %)	12 (23.1 %)
Citrate cycle (TCA cycle)	22	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)
Fatty acid biosynthesis	21	11 (52.4 %)	11 (52.4 %)	11 (52.4 %)
Glycine, serine and threonine metabolism	57	21 (36.8 %)	21 (36.8 %)	21 (36.8 %)
Glycolysis / Gluconeogenesis	41	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)
Glyoxylate and dicarboxylate metabolism	58	11 (19.0 %)	12 (20.7 %)	12 (20.7 %)
Lysine biosynthesis	31	13 (41.9 %)	13 (41.9 %)	13 (41.9 %)
Nicotinate and nicotinamide metabolism	47	15 (31.9 %)	12 (25.5 %)	12 (25.5 %)
Propanoate metabolism	47	9 (19.1 %)	9 (19.1 %)	9 (19.1 %)
Pyruvate metabolism	64	19 (29.7 %)	20 (31.2 %)	20 (31.2 %)
Synthesis and degradation of ketone bodies	6	4 (66.7 %)	4 (66.7 %)	4 (66.7 %)
Valine, leucine and isoleucine biosynthesis	18	14 (77.8 %)	14 (77.8 %)	14 (77.8 %)



The Citric Acid Cycle

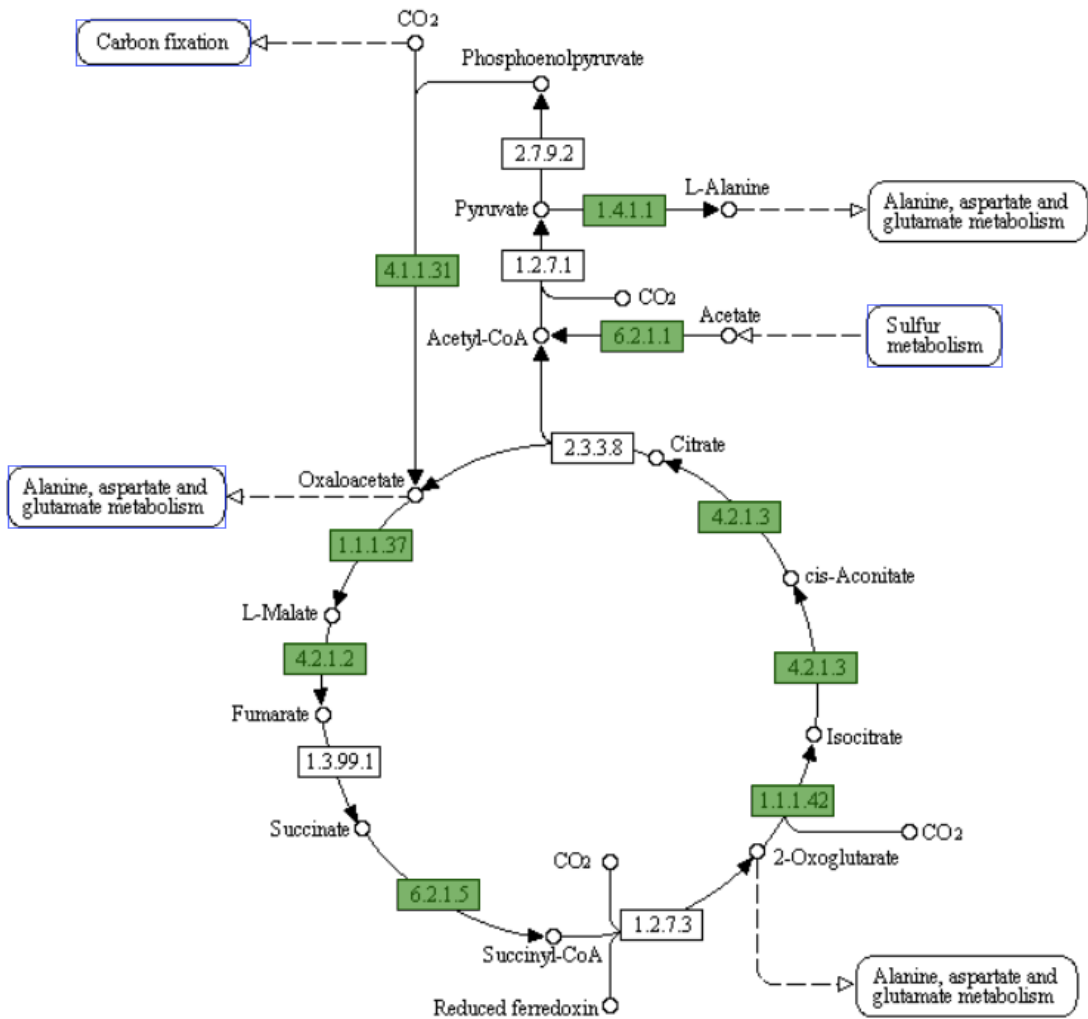
KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicycler	Unknown sp. 107unicycler
Alanine, aspartate and glutamate metabolism	43	20 (46.5 %)	18 (41.9 %)	18 (41.9 %)	18 (41.9 %)
Arginine and proline metabolism	97	26 (26.8 %)	18 (18.6 %)	18 (18.6 %)	18 (18.6 %)
Ascorbate and aldarate metabolism	44	8 (18.2 %)	7 (15.9 %)	7 (15.9 %)	7 (15.9 %)
Citrate cycle (TCA cycle)	22	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)
D-Glutamine and D-glutamate metabolism	13	4 (30.8 %)	3 (23.1 %)	3 (23.1 %)	3 (23.1 %)
Fatty acid biosynthesis	21	11 (52.4 %)	11 (52.4 %)	11 (52.4 %)	11 (52.4 %)
Fatty acid elongation in mitochondria	8	3 (37.5 %)	3 (37.5 %)	3 (37.5 %)	3 (37.5 %)
Fatty acid metabolism	29	8 (27.6 %)	8 (27.6 %)	8 (27.6 %)	8 (27.6 %)
Glycolysis / Gluconeogenesis	41	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)
Glyoxylate and dicarboxylate metabolism	58	11 (19.0 %)	12 (20.7 %)	12 (20.7 %)	12 (20.7 %)
Tyrosine metabolism	63	11 (17.5 %)	9 (14.3 %)	9 (14.3 %)	9 (14.3 %)
Valine, leucine and isoleucine degradation	34	17 (50.0 %)	17 (50.0 %)	17 (50.0 %)	17 (50.0 %)



Reductive CAC in Photosynthetic Bacteria (only one present)

KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicyler	Unknown sp. 107unicyler
Alanine, aspartate and glutamate metabolism	43	20 (46.5 %)	18 (41.9 %)	18 (41.9 %)	18 (41.9 %)
Carbon fixation in photosynthetic organisms	25	14 (56.0 %)	14 (56.0 %)	14 (56.0 %)	14 (56.0 %)
Reductive carboxylate cycle (CO2 fixation)	13	8 (61.5 %)	8 (61.5 %)	8 (61.5 %)	8 (61.5 %)
Sulfur metabolism	30	6 (20.0 %)	6 (20.0 %)	6 (20.0 %)	6 (20.0 %)

REDUCTIVE CARBOXYLATE CYCLE IN PHOTOSYNTHETIC BACTERIA



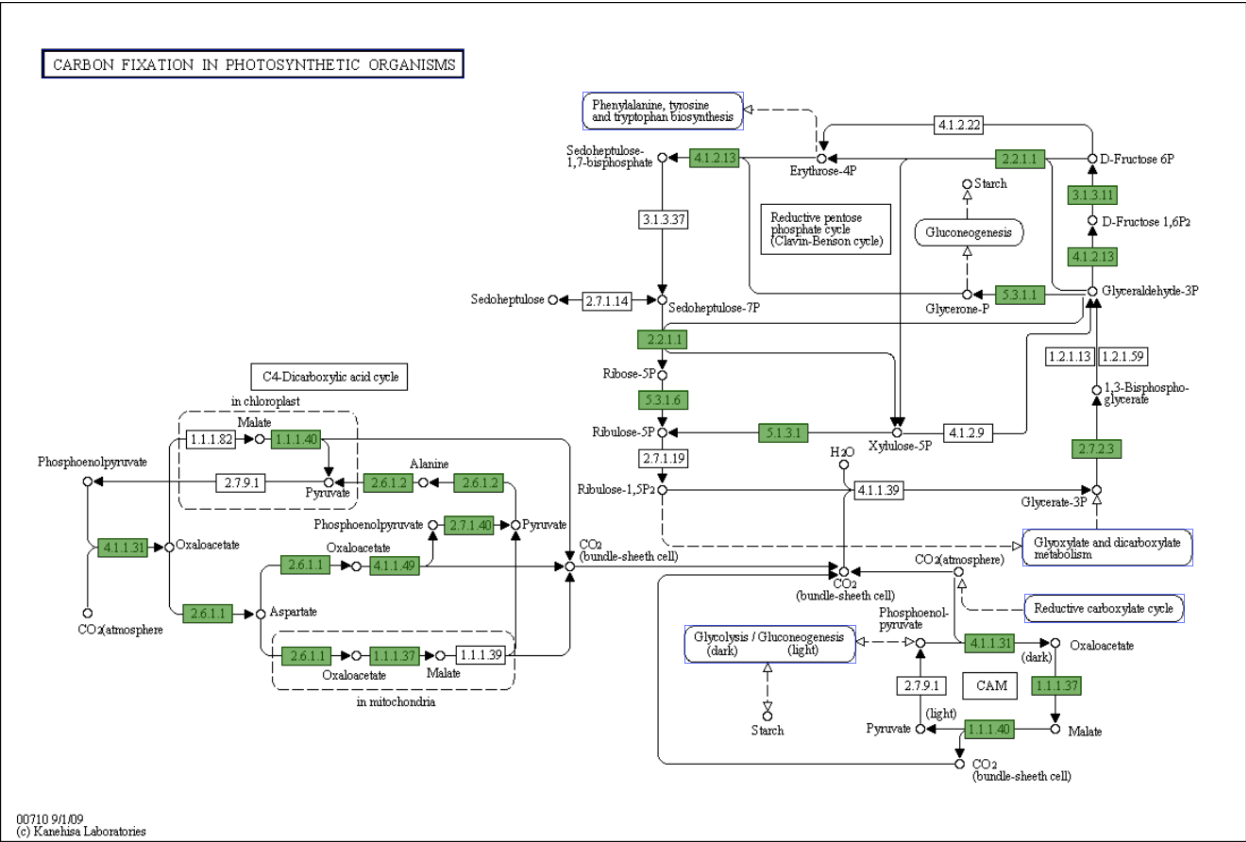
00720 9/1/09
(c) Kanehisa Laboratories

Reductive CAC (CO₂ fixation)

See above

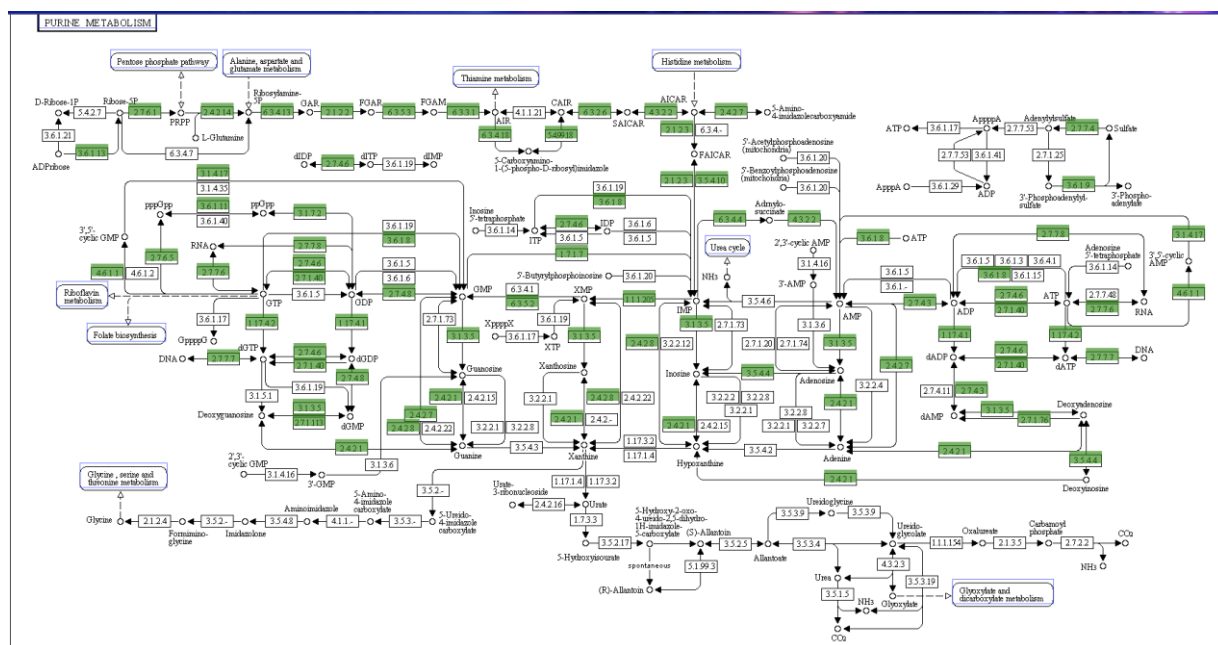
Carbon fixation in photosynthetic organisms

KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicycler	Unknown sp. 107unicycler
Carbon fixation in photosynthetic organisms	25	14 (56.0 %)	14 (56.0 %)	14 (56.0 %)	14 (56.0 %)
Glycolysis / Gluconeogenesis	41	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)	18 (43.9 %)
Glyoxylate and dicarboxylate metabolism	58	11 (19.0 %)	12 (20.7 %)	12 (20.7 %)	12 (20.7 %)
Phenylalanine, tyrosine and tryptophan biosynthesis	31	20 (64.5 %)	20 (64.5 %)	20 (64.5 %)	20 (64.5 %)
Reductive carboxylate cycle (CO2 fixation)	13	8 (61.5 %)	8 (61.5 %)	8 (61.5 %)	8 (61.5 %)

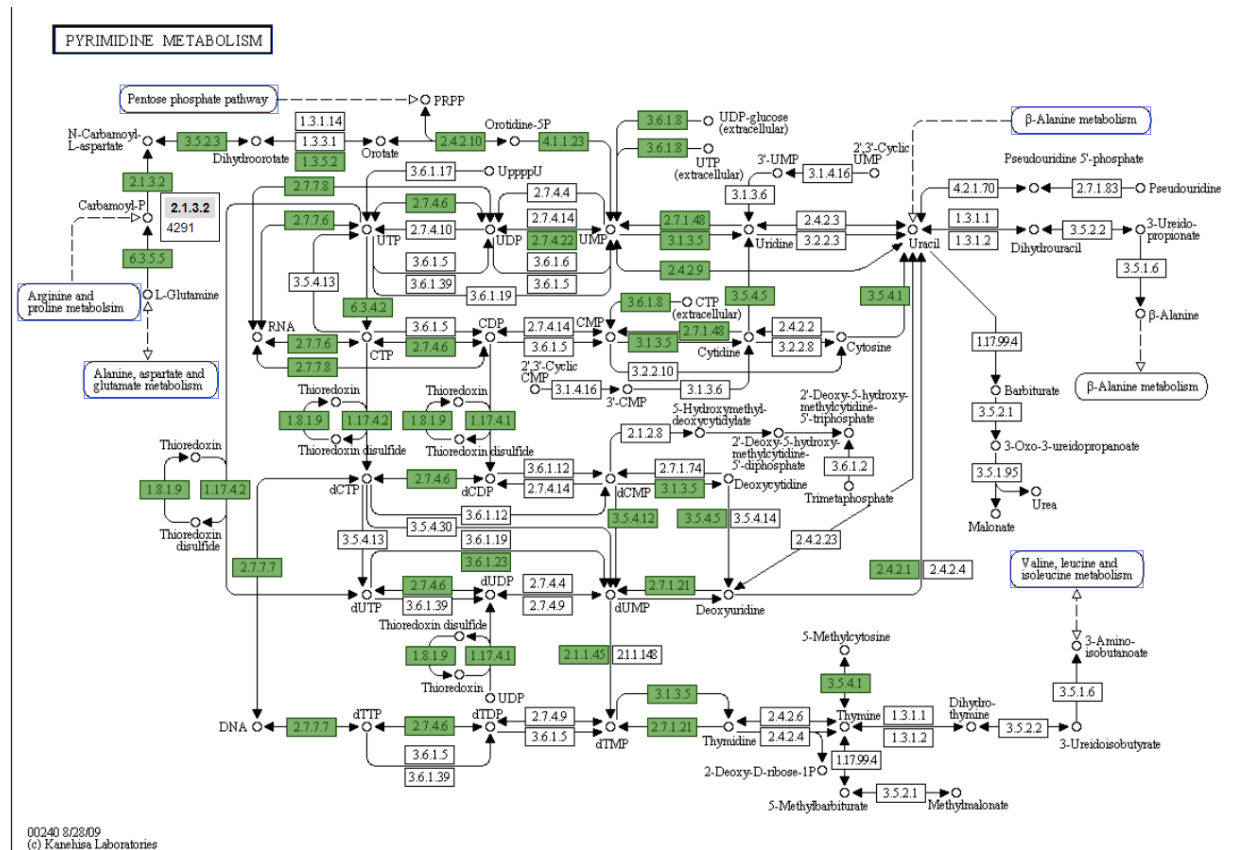


Purine Metabolism

KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicycler	Unknown sp. 107unicycler
	0	0	0	0	0
Alanine, aspartate and glutamate metabolism	43	20 (46.5 %)	18 (41.9 %)	18 (41.9 %)	18 (41.9 %)
Folate biosynthesis	25	13 (52.0 %)	13 (52.0 %)	13 (52.0 %)	13 (52.0 %)
Glycine, serine and threonine metabolism	57	21 (36.8 %)	21 (36.8 %)	21 (36.8 %)	21 (36.8 %)
Glyoxylate and dicarboxylate metabolism	58	11 (19.0 %)	12 (20.7 %)	12 (20.7 %)	12 (20.7 %)
Histidine metabolism	37	16 (43.2 %)	15 (40.5 %)	15 (40.5 %)	15 (40.5 %)
Pentose phosphate pathway	37	17 (45.9 %)	18 (48.6 %)	18 (48.6 %)	18 (48.6 %)
Purine metabolism	104	42 (40.4 %)	39 (37.5 %)	39 (37.5 %)	39 (37.5 %)
Riboflavin metabolism	16	10 (62.5 %)	9 (56.2 %)	9 (56.2 %)	9 (56.2 %)
Thiamine metabolism	16	6 (37.5 %)	5 (31.2 %)	5 (31.2 %)	5 (31.2 %)

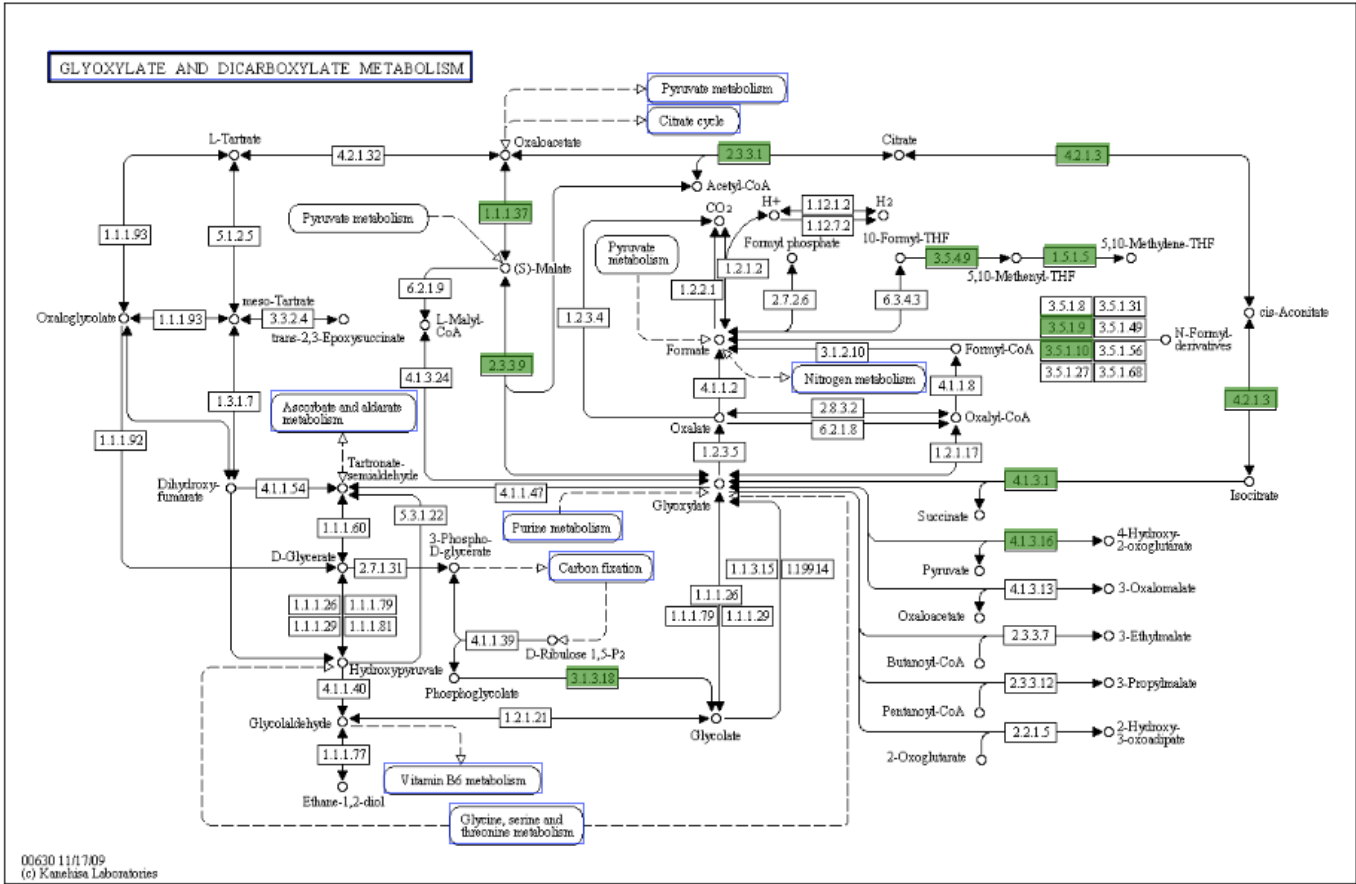


KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicycler	Unknown sp. 107unicycler
Alanine, aspartate and glutamate metabolism	43	20 (46.5 %)	18 (41.9 %)	18 (41.9 %)	18 (41.9 %)
Arginine and proline metabolism	97	26 (26.8 %)	18 (18.6 %)	18 (18.6 %)	18 (18.6 %)
Pentose phosphate pathway	37	17 (45.9 %)	18 (48.6 %)	18 (48.6 %)	18 (48.6 %)
Pyrimidine metabolism	64	26 (40.6 %)	24 (37.5 %)	24 (37.5 %)	24 (37.5 %)
Valine, leucine and isoleucine degradation	34	17 (50.0 %)	17 (50.0 %)	17 (50.0 %)	17 (50.0 %)
beta-Alanine metabolism	32	4 (12.5 %)	4 (12.5 %)	4 (12.5 %)	4 (12.5 %)



Glyoxylate and Dicarboxylate metabolism

KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicycler	Unknown sp. 107unicycler
Ascorbate and aldarate metabolism	44	8 (18.2 %)	7 (15.9 %)	7 (15.9 %)	7 (15.9 %)
Carbon fixation in photosynthetic organisms	25	14 (56.0 %)	14 (56.0 %)	14 (56.0 %)	14 (56.0 %)
Citrate cycle (TCA cycle)	22	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)
Glycine, serine and threonine metabolism	57	21 (36.8 %)	21 (36.8 %)	21 (36.8 %)	21 (36.8 %)
Glyoxylate and dicarboxylate metabolism	58	11 (19.0 %)	12 (20.7 %)	12 (20.7 %)	12 (20.7 %)
Nitrogen metabolism	57	18 (31.6 %)	14 (24.6 %)	14 (24.6 %)	14 (24.6 %)
Purine metabolism	104	42 (40.4 %)	39 (37.5 %)	39 (37.5 %)	39 (37.5 %)
Pyruvate metabolism	64	19 (29.7 %)	20 (31.2 %)	20 (31.2 %)	20 (31.2 %)
Vitamin B6 metabolism	26	5 (19.2 %)	5 (19.2 %)	5 (19.2 %)	5 (19.2 %)

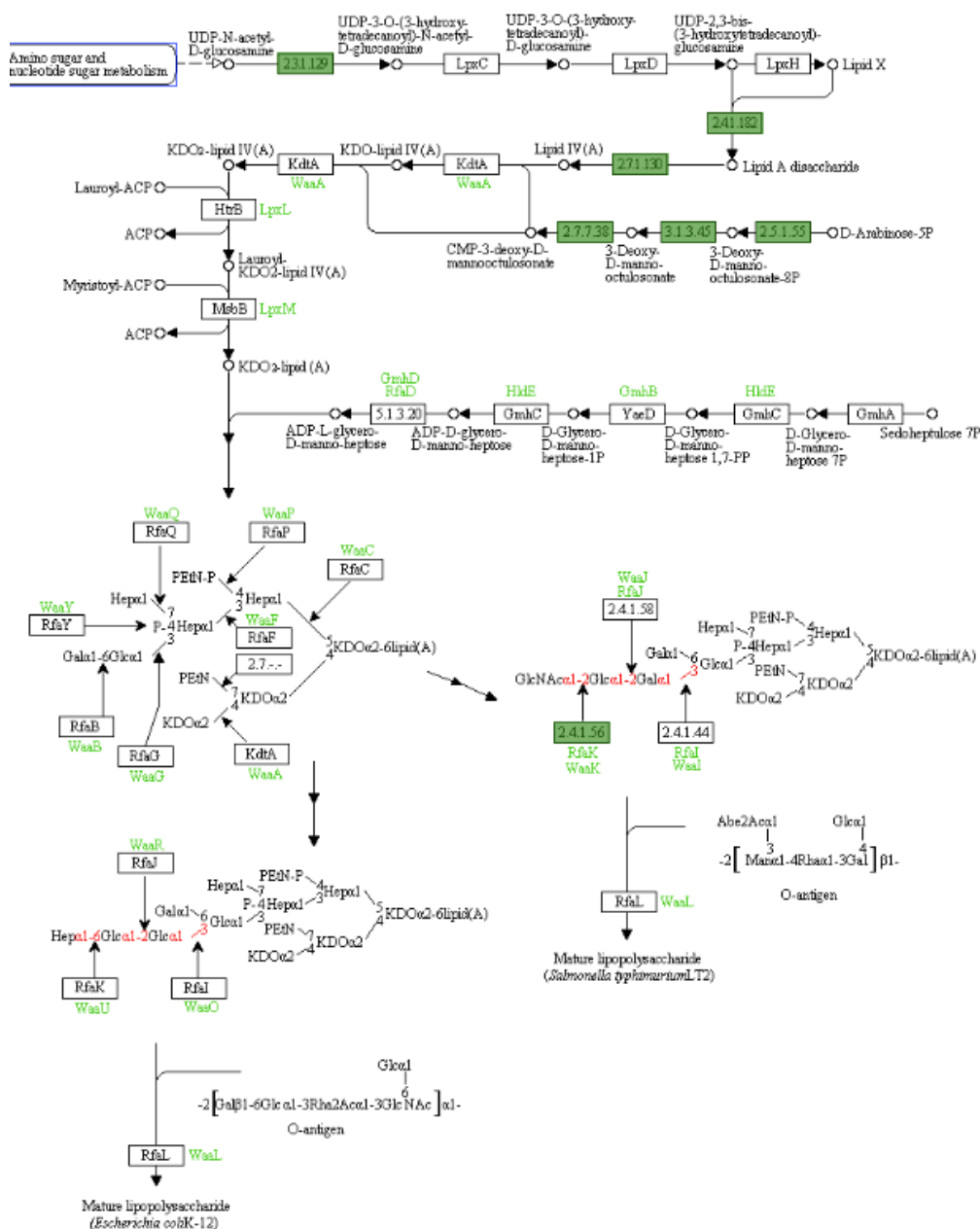


KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shoviti	Unknown sp. 107unicycler	Unknown sp. 107unicycler
Alanine, aspartate and glutamate metabolism	43	20 (46.5 %)	18 (41.9 %)	18 (41.9 %)	18 (41.9 %)
Aminoacyl-tRNA biosynthesis	31	23 (74.2 %)	21 (67.7 %)	21 (67.7 %)	21 (67.7 %)
Arginine and proline metabolism	97	26 (26.8 %)	18 (18.6 %)	18 (18.6 %)	18 (18.6 %)
Cysteine and methionine metabolism	64	20 (31.2 %)	17 (26.6 %)	17 (26.6 %)	17 (26.6 %)
Glycine, serine and threonine metabolism	57	21 (36.8 %)	21 (36.8 %)	21 (36.8 %)	21 (36.8 %)
Histidine metabolism	37	16 (43.2 %)	15 (40.5 %)	15 (40.5 %)	15 (40.5 %)
Lysine biosynthesis	31	13 (41.9 %)	13 (41.9 %)	13 (41.9 %)	13 (41.9 %)
Phenylalanine, tyrosine and tryptophan biosynthesis	31	20 (64.5 %)	20 (64.5 %)	20 (64.5 %)	20 (64.5 %)
Tryptophan metabolism	67	15 (22.4 %)	13 (19.4 %)	13 (19.4 %)	13 (19.4 %)
Valine, leucine and isoleucine biosynthesis	18	14 (77.8 %)	14 (77.8 %)	14 (77.8 %)	14 (77.8 %)

Lipopolysaccharide Biosynthesis

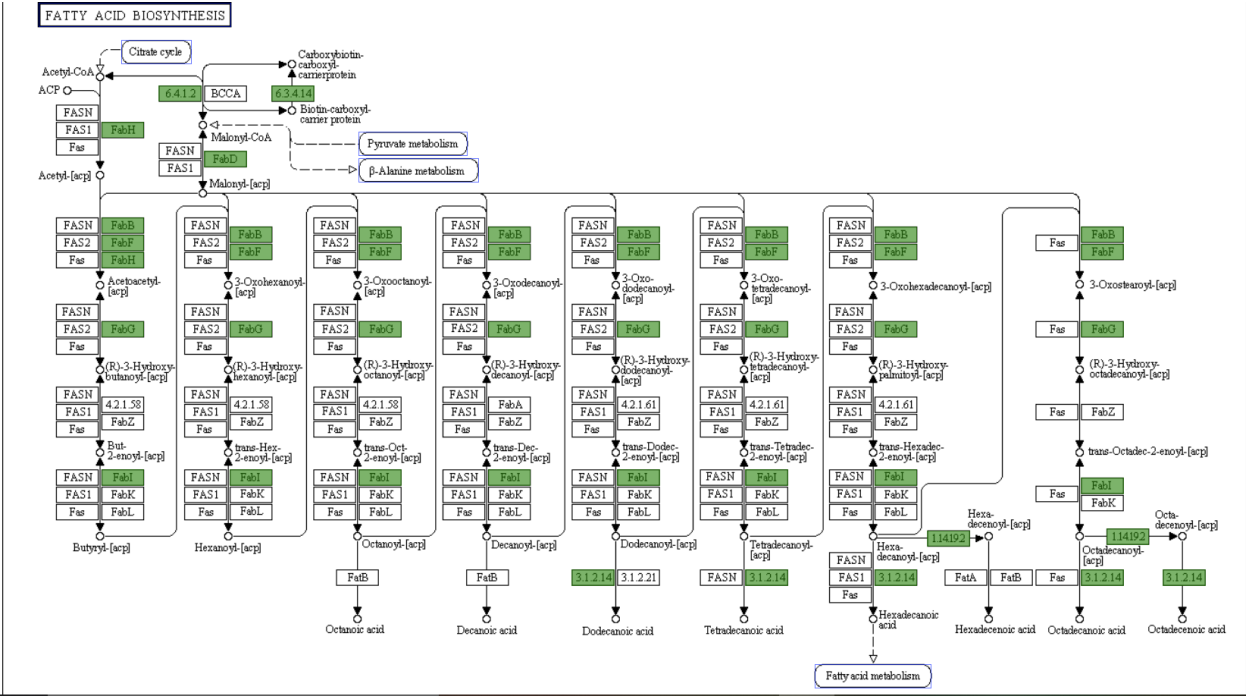
KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicyler	Unknown sp. 107unicyler
Amino sugar and nucleotide sugar metabolism	94	30 (31.9 %)	29 (30.9 %)	29 (30.9 %)	29 (30.9 %)
Lipopolysaccharide biosynthesis	22	14 (63.6 %)	10 (45.5 %)	10 (45.5 %)	10 (45.5 %)

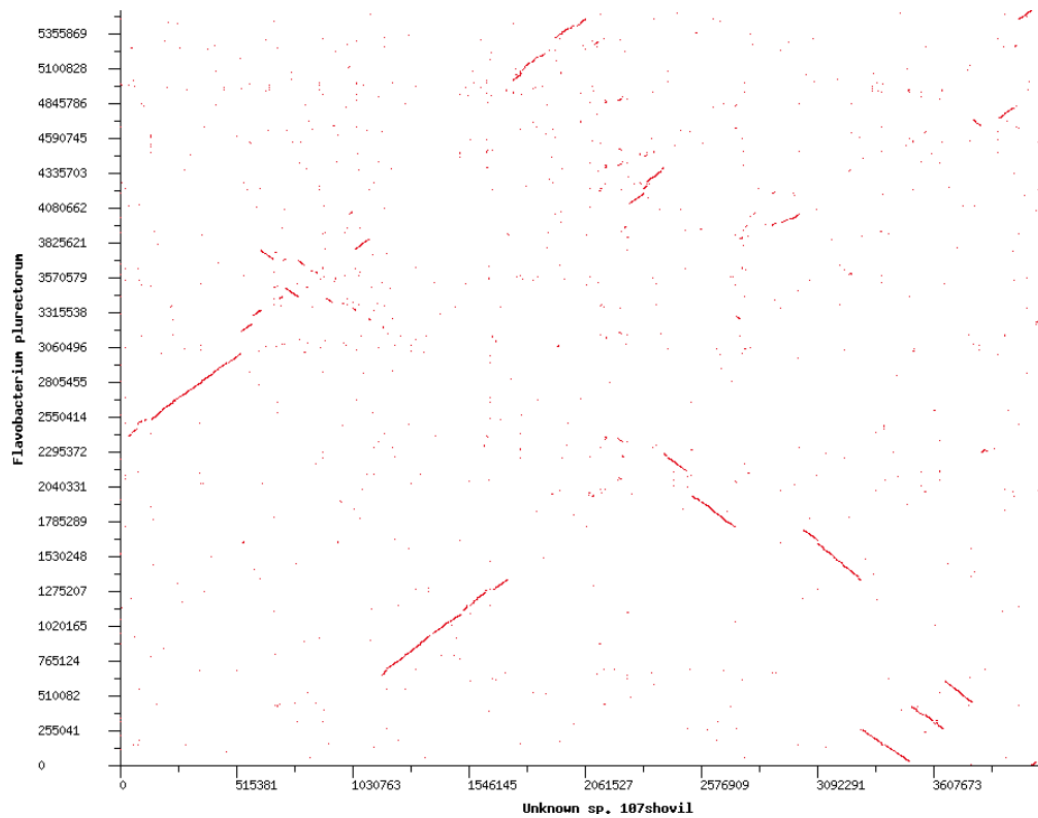
LIPOPOLYSACCHARIDE BIOSYNTHESIS

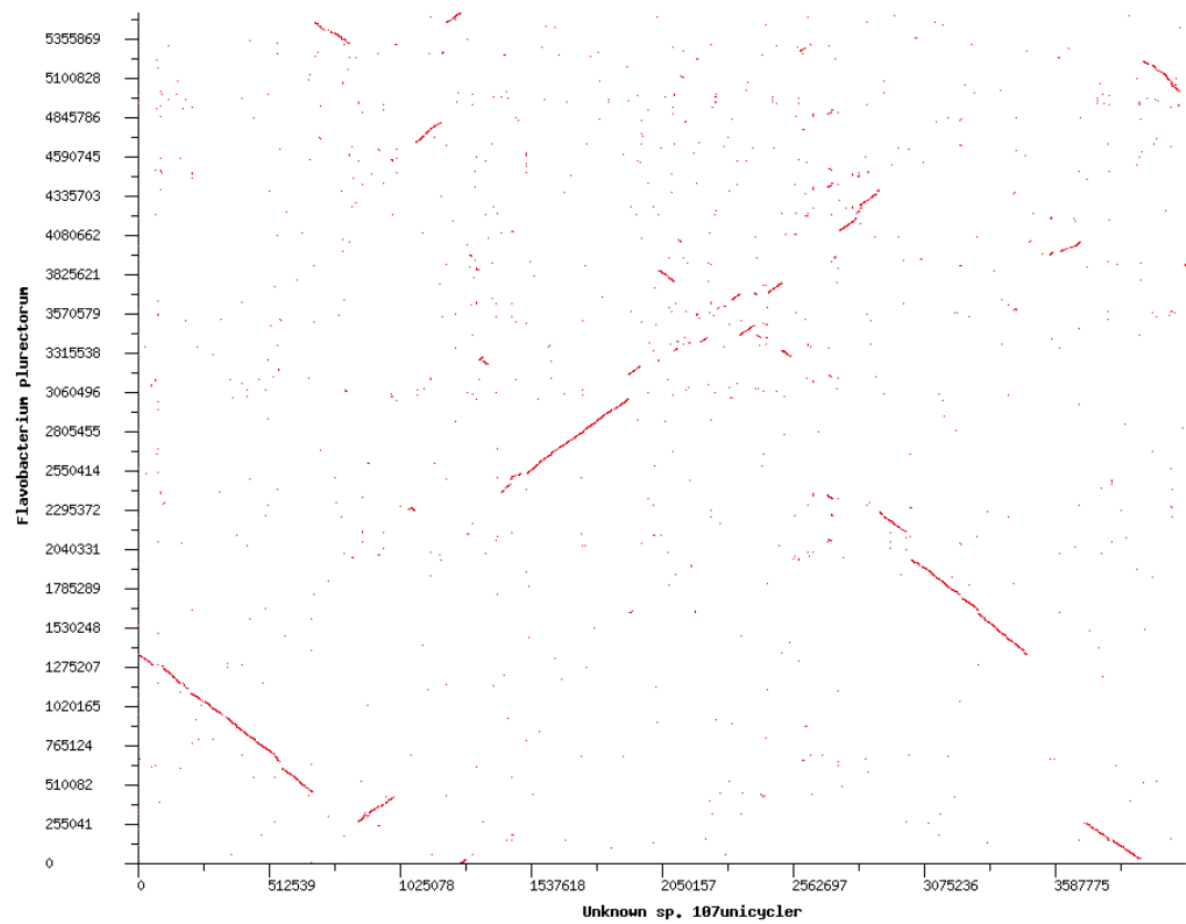


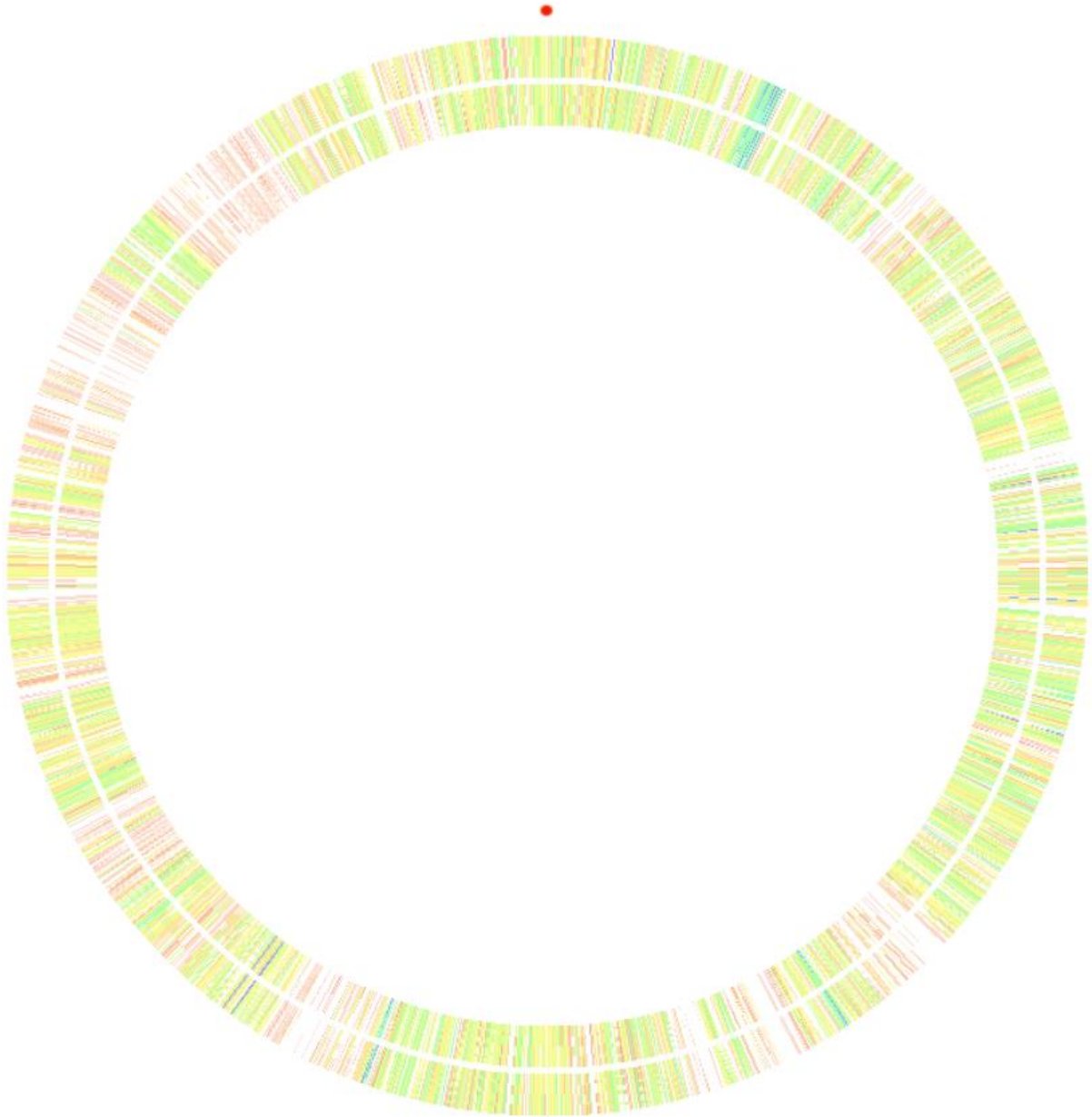
Fatty Acid Biosynthesis

KEGG map	Distinct ECs	Flavobacterium plurectorum	Unknown sp. 107shovil	Unknown sp. 107unicycler	Unknown sp. 107unicycler
Citrate cycle (TCA cycle)	22	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)	13 (59.1 %)
Fatty acid biosynthesis	21	11 (52.4 %)	11 (52.4 %)	11 (52.4 %)	11 (52.4 %)
Fatty acid metabolism	29	8 (27.6 %)	8 (27.6 %)	8 (27.6 %)	8 (27.6 %)
Pyruvate metabolism	64	19 (29.7 %)	20 (31.2 %)	20 (31.2 %)	20 (31.2 %)
beta-Alanine metabolism	32	4 (12.5 %)	4 (12.5 %)	4 (12.5 %)	4 (12.5 %)









Nestler 1

Jayden Nestler

Dr. Sheridan

Bacteriophage Research

In the laboratory, I have acquired and honed a diverse set of skills, ranging from fundamental microbiology techniques like aseptic practice to more intricate procedures such as DNA isolations. Upon initially joining the lab, I was hesitant in executing even the basic techniques. However, over time, I not only developed a heightened confidence in my skills but also gained a profound understanding of the underlying reasons for our methodologies.

My involvement in this lab marked several firsts, including my initial experience with a dilution series, recognition of phage, overlays, agar preparation, centrifuge operation, autoclave usage, etc. These experiences have contributed significantly to my deepened comprehension of microbiology, fostered by the questions I've been able to pose during lab sessions.

Beyond the enrichment of my knowledge, my engagement in the lab has positively influenced my career goals. It has heightened my awareness of opportunities on campus, leading to my role as an undergraduate teaching assistant this Fall semester. Additionally, I intend to leverage this research experience when applying to medical schools and potentially enhancing my job resumes.

Furthermore, my time in the lab has sparked contemplation about pursuing a master's degree in microbiology, a decision that requires further consideration. I didn't expect to enjoy the idea and process of research as much as I have and am truly thankful for the experience I have had here at Idaho State University.

Applicant	Salary Requested	Supplies Requested	Travel Requested	Total Requested	Poster Size	Salary Received	Supplies Received	Travel Received	Total Received	Salary Dispersed	MAX 500	MAX 2800
Anika Busz	2550	1600	190	4340	6X25X15	2250	500		2750	2750		2750
Beknazar Tursyngazy	1500	0	0	1500	10X10X15	1500			1500			1500
Caden Freeman	5500	0	0	5500	0	0	0	0	0	0		0
Carly Helbling	1500	0	0	1500	10X10X15	1500			1500			1500
Cornelius Sia	2193	1590	202.5	3985.5	3X28X15	1260	500		1760	1760		1760
Dong Le	5500	0	0	5500	10X28X15	4200			4200			2800
Kenneth Wareham	0	3994.96	0	3994.96	0	0	0	0	0	0		0
Kylie Wilson	1377	400	2650	4427	3X27X15	1215	400	100	1715	1715		1715
Madilyn Sorenson	3360	0	0	3360	8X28X15	3360			3360	3360		2800
McKenzie Bowey	1536	121	0	1657	10X10X15	1500	121		1621	1621		1621
Riley Ziegler	1500	0	0	1500	10X10X15	1500			1500			1500
Sara Muehlhausen	2100	0	251.64	2351.64	5X28X15	2100		251.64	2351.64	2351.64		2352
Shastine Huddelston	2550	600	1850	5000	6X25X15	2250	500		2750	2750		2750
Adyson Clabby	360	630	0	990	4X6X15	360	630	0	990	990		990
Hannah Broyles	360	630	0	990	4X6X15	360	630	0	990	990		990
Ashley Bachman	180	78.5	19.44	277.94	3X6X10	180	0	78.5	258.5	258.5		258.5
Josh Chapman	180	78.5	19.44	277.94	3X6X10	0	0	0	0			0
Dale Takalo	180	78.5	19.44	277.94	3X6X10	0	0	0	0			0
TOTAL		9644.46	5144.14	46596.1					27246.14	18287.64		25286
		5649.5										
								32895.64				

Grand Totals		
Dispersed Supplies	Dispersed Salary	Dispersed Fringe/Overtime
2657.31	30161.57	961.07

***STRATEGIC INITIATIVE
Undergraduate Research Funding for
STEM Majors at the University of Idaho
FINAL PROJECT REPORT***

*Submitted to:
Higher Education Research Council
Idaho State Board of Education
P.O. Box 83720
Boise, Idaho 83720-0037*

*Submitted by:
University of Idaho Office of Undergraduate Research
875 Perimeter Drive
Moscow, ID 83844
October 31, 2023*

Table of Contents

EXECUTIVE SUMMARY.....Page 3

SBoE Supported Summer Undergraduate Research Fellowships (SURF).....Pages 4-15

- 1.0 Project Summary Report.....Dillon West (Biological Eng.)
- 2.0 Project Summary Report.....Lacey Hunt (Computer Sci)
- 3.0 Project Summary Report.....Daniel Blanchette (Biol Sci)
- 4.0 Project Summary Report.....Destinee Ditton (Biol. Eng.)
- 5.0 Project Summary Report.....William Auten (Chem./Phys)
- 6.0 Project Summary Report.....Peter Wieber (Biol Eng.)
- 7.0 Project Summary Report.....Jennie Tafoya (Comp Sci)
- 8.0 Project Summary Report.....Juwon Elelu (Elec Eng.)
- 9.0 Project Summary Report.....Katherine Ryssel (AVFS)
- 10.0 Project Summary Report.....Alyssa Livingston (Wildlife)
- 11.0 Project Summary Report.....Mason Kilker (Chem)
- 12.0 Project Summary Report.....Zaiden Espe (Math)

OUR Supported Summer Students.....Pages 16-19

- 13.0 OUR Supported Summer Project.....Alexandro Aguilar (Music)
- 14.0 OUR Supported Summer Project.....Kendall Mitton (Poli. Sci.)
- 15.0 OUR Supported Summer Project.....Amara Bailey (Crim. Just.)
- 16.0 OUR Supported Summer Project.....Hunter Rouse (Mov. Sci.)

Appendix 1: Copies of ICUR Posters for SBoE supported SURF Students

Appendix 2: Copies of Posters for OUR supported Summer Students

Executive Summary

Undergraduate research is recognized as a high-impact educational practice that increases the rates of student retention and engagement. At the University of Idaho, it is practiced throughout all units on campus, and it is centrally placed in the institution's strategic plan. The Office of Undergraduate Research (OUR) is taking the lead in enabling research opportunities for undergraduates at UI as it manages various competitive student grant programs that directly support student research.

During AY 2022-23, generous funding from the State Board of Education (SBoE) permitted UI to continue its Summer Undergraduate Research Fellowship (SURF) Program. This intensive 10-week summer research experience actively engages undergraduates in faculty-mentored, independent research. Over the course of the program, students are mentored toward increased independence on their projects. Each student is provided with a \$5,000 stipend in the form of a fellowship which allows them to devote full time effort to their projects. Each student is also provided with \$1,000 to help offset materials and supplies and other project-related expenses. Selection of student participants is a competitive process in which students submit research proposals to the Office of Undergraduate Research and the Director utilizes faculty affiliates in each college to review the proposals and provide selections. The Director then makes sure that projects all well-represented across colleges. It is important to note that not all projects this cycle required a supply budget. This allowed for us to fund additional students with SBoE funds. For FY 2022-23, the SBoE funding supported **12 SURF** awards. All these students supported by SBoE funds attended and presented the results of their projects at the 2023 Virtual Idaho Conference on Undergraduate Research in July of 2023. These students will also be required to present their results at the UI Undergraduate Research Symposium on April 22, 2024.

Additionally, due to partnerships with programs such as Idaho INBRE as well as various departments on campus, the OUR was able to support **an additional 4 Summer Student projects** that, while outside of STEM disciplines, provided excellent research experiences to these undergraduates. These students were also required to present at the virtual ICUR 2023 and summaries of their projects and a few of their posters are also provided in this report.

End of project feedback from students and their mentors was overwhelmingly positive. Significantly, none of the undergraduate research projects described here would have been possible without the support provided by the State Board of Education. We sincerely thank the Higher Education Research Council and the Idaho State Board of Education for making these experiences possible for our students.

Sincerely,

Kristopher V. Waynant
Director, Office of Undergraduate Research
Associate Professor, Chemistry
kwaynant@uidaho.edu

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Dillon West**

Faculty Mentor: *Nathan Schiele, Biological Engineering*

Project Title: *Investigating the Effects of TGF- β R2 Inhibition in Mesenchymal Stem Cells*

Abstract: Tendons transfer forces from muscle to bones and are vital in joint movement and injury prevention. However, they have poor self-regeneration capabilities and current rehabilitations are unable to restore damaged tendons to their prior strength. Tissue engineering using mesenchymal stem cells (MSCs) is widely being investigated as a potential means of functional tendon replacement or repair. A current obstacle in this field is the lack of thorough understanding of how to direct MSCs differentiation into specialized tendon cells and control functional tendon formation. The cytokine TGF- β is known to play a key role in this, though its specific mechanisms and signal propagation require further investigation. This research will examine the effects of inhibiting TGF- β type-II receptor to create a better understanding of its signaling pathways within the cell and its role in the production of functional tendon markers. The outcomes of this research will enhance the field of tendon tissue engineering by exposing potential pathways responsible for functional tendon marker creation, allowing for more informed manipulation of MSCs in future studies and regenerative therapies.

Objectives: **Obj. 1:** Inhibit TGF- β R2 via the chemical Morin and identify impacts on LOX and downstream signaling. **Obj. 2:** Inhibit TGF- β R2 via RNA interference and identify impacts on LOX and downstream signaling.

Results: Morin Inhibition: Initial experiments utilizing morin as a chemical inhibitor required a few iterations as high concentrations of DMSO resulted in cytotoxic effects on the cell cultures (Fig.1A). The first solution of morin in DMSO at 50 μ M prepared resulted in a concentration of about 10% DMSO in cell media, which had cytotoxic effects on the cells. The second attempt of preparing a suitable solution resulted in a 2% concentration of DMSO in media, however cytotoxicity was still present. The third attempt allowed a 0.5% concentration and had negligible effects on the cells. However, treatment and morin control groups showed little to no difference in cell morphology, which indicated ineffective inhibition. Western blot analysis further proved morin as an ineffective choice for chemical inhibition of TGF- β R2.

RNA Interference Inhibition: Fluorescent control indicated only the 10 nM concentrations of the constructs had successful transfection into the cells, which led to the 0.1 and 1 nM concentration groups being disregarded. The siRNA construct S1 showed the most effective inhibition based on cell morphology, and its LOX protein band was lighter compared to the negative control construct when evaluated with a western blot, which indicates that TGF- β R2 does play a role in the production of LOX.

Discussion & Future Direction: Morin appears to be an ineffectual choice for inhibition of TGF- β R2 based on the experiments conducted here and the limited literature supporting it. Once the DMSO cytotoxicity was no longer an obstruction, qualitative analysis indicated no substantial difference between morin-treated cell groups and its controls. RNA interference, on the other hand, was able to effectively inhibit TGF- β R2, which negatively impacted LOX levels. This indicates that TGF- β R2 may be crucial in the production of LOX. However, this experiment so far is only n=1, and therefore needs to have further technical replicates ran to validate the initial findings. In the future, the protocol for siRNA inhibition will be ironed out, and the experiments will be repeated to ensure consistency of outcomes.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks. Spent \$538 on supplies.

Acknowledgement: This student's poster is included in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Lacey Hunt**

Faculty Mentor: *John Shovic, Electrical Engineering*

Project Title: *Precision Agriculture Adoption and Integration Case Study*

Abstract: Remote sensing systems for precision agriculture allow for technology and automation to improve the profitability and sustainability of modern farms. The adoption of these systems in the United States has been slow, due to the high cost and difficulty using them. The University of Idaho, in collaboration with Laurel Grove Wine Farm in Winchester, Virginia, has been in the process of developing a remote sensing system designed to be low-cost and flexible in its agricultural applications. This new system lacks deterministic testing results for (1) reliability, (2) overall cost, and (3) usability by farmers. This research project aims to test the system's performance in a new application domain: a heritage apple orchard at Sandpoint Organic Agriculture Center. This proposal outlines the tasks related to testing the performance, cost, and user-interaction of the remote sensing system to determine its viability in furthering the usage of precision agriculture in the United States.

Objective: Assembly and Installation of SCARECRO

The researcher installed a fully functioning instance of the SCARECRO system into SOAC consisting of two WeatherRack stations, two Datagators, two Gateways (one for use in the orchard, the other stored locally for testing purposes), and one Middle Agent. A new database instance was also established, as well as physical building of hardware supports in the orchard. An explanation of SCARECRO's operational architecture is necessary for later exception and fault troubleshooting explanations. The WeatherRacks collect environmental data such as temperature, humidity, rainfall, wind speed and direction, and sunlight. These sensor readings are sent to the Gateway via a wired connection, Bluetooth, or 433MHz radio waves depending on the type of sensor. The Datagators collect readings from sensors that are located farther from the Gateway (in this case, soil moisture sensors) and transmit this data to the Gateway via MQTT through a local Wi-Fi Hotspot. The Gateway is responsible for eliminating duplicate messages, keeping track of sensor connections, and sending data to the Middle Agent. The Gateway sends data to the Middle Agent, a cloud computer which handles all data transmission between the Gateway and the database, via MQTT through a Wi-Fi connection to AirVandal Gold. The database stores all collected data for the SOAC installation, which can be retrieved via database queries for display on a dashboard website or used in AI research applications. All components are solar-powered, so South-facing solar supports were also built into each component stand.

Conclusions: This case study demonstrated successful implementation of the SCARECRO system into an entirely new application domain. This system, even after unprecedented obstacles, proved this specific data collection method to be more cost-effective and robust than its commercially available competitors. Currently, despite this system being not quite ready for widespread deployment, is on the right track to be a viable option for a wide variety of agricultural settings looking to incorporate important precision agriculture methods into their work. To further develop the SCARECRO system towards widespread availability, more work must be completed. Some future projects that would aid in this process include other test sites, incorporation of the SOAC horticulturist sensor suggestions, research into the cause of the periodic disconnection from the network, and further troubleshooting of Datagators on site. A new test site (piloted with the locally assembled test Gateway) would allow further conclusions and improvements to be made regarding the implementation of this system in a different agricultural application.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks. A series of electrical equipment and data sensors were also purchased for this project totalling \$854.

Acknowledgement: Poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Daniel Blanchette**

Faculty Mentor: *Diana Mitchell, Biological Sciences*

Project Title: *Segmentation analyses to identify and quantify microglia in 3D image stacks*

Abstract: Using time-lapse confocal microscopy to record and observe microglia behavior in living zebrafish embryos, the Mitchell lab investigates the molecular basis of dynamic migration and phagocytic behavior of microglia in the central nervous system. Microglial cells regulate brain development, maintain neuronal networks, and repair neural injuries. Timelapse imaging provides crucial insight into the behavior of these cells. Other methods, such as manual cell counting, are subject to human bias and are tedious, repetitive, and time-consuming. The Long computer science lab utilizes Python and open-source modules to develop an automated pipeline as a programmatic solution. These methods aim to expedite and optimize the lab's manual processes. This research project seeks to segment microglia when applied to 3D time series image stacks. Computer segmentation of microglia imaging relies on pixel values to generate bitmasks. Microglia segmentation is challenging because the cell's irregular shape and size can be obscured, resulting in omitted pixel intensity values. Two programs were developed to test the viability of Otsu, multi-Otsu, and Yen automatic thresholding[2]. Both methods separate the raw image into two layers: the foreground and background. Numerical data is generated via histograms to predict optimal threshold values for each algorithm. Prototype implementations of these programs demonstrate viability for microglia counting. However, misclassification of microglia occurs when the predicted pixel threshold is outside the histogram's range. Further refinement of these programs is crucial as they will be foundational for future object classification methods and microglia tracking, optimizing the lab's data processing capabilities and time.

Objectives and Results: The prototype program takes an entire directory tree (folders and subfolders) from the researcher's computer after they adjust the path for their image data. Users also designate an output folder path(to the desktop or otherwise) for storing the results. The thresholding methods of the program are applied to each image in the video frame subfolders. For debugging and lab conformation, a .csv file is generated with data for each frame, z stack position, cell counts, what branched value was used for the threshold, and the threshold value. To help with misclassification, other algorithms can be used to separate the objects. Canny edge detection may be a viable way to distinguish cells close to one another. The overall goal is to ensure separation in all frames of the z-stack to render microglia in 3D space accurately. However, misclassification is not a deal breaker for the lab as their metrics include margins of error for the traditional method of manual counting. While the program being off by one on the cell count may not impact data collection. However, cases where the program counts are greater than or equal to ten cells, may risk skewing the results to the detriment of the lab. One performed better than the other for these programs(Otsu and Yen). Key findings suggest that while both suffered from object misclassification, Otsu and Multi-Otsu were better at setting thresholds to include pixel values closely related. On the other hand, the Multi-Otsu and Yen program performed better when there were high differences between pixel intensity values. Based on the preliminary data, Multi-Otsu and Otsu for the branching logic was the better choice. As segmentation is the foundation for all tracking methods to follow, it is paramount to continue to refine the current program and iterate upon it until a viable cell count is produced. The next step is to classify these 3D objects' shapes for the microglia and upload them to a database. This step will be daunting due to the permutations of known microglia shapes and others that require further observational research via recordings. Once these pieces are in place, tracking methods utilize machine learning and Artificial Intelligence(A.I.) to predict better what composes microglia from the rest of an image.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Destinee Ditton**

Faculty Mentor: *Nathan Schiele, Biological Engineering*

Project Title: *Visualization of Tendon Organization of Rat Tails and Hindlimbs in 3D Using Micro-CT*

Abstract: Tendons are connective, collagenous tissues that transmit mechanical forces to allow for body movement, but tendons injure easily and have poor healing capabilities. New treatment methods are needed, requiring a better understanding of multiscale structure-function relationships through comprehensive imaging. Micro-computed tomography (CT) is an imaging modality that produces three-dimensional (3D), high-resolution images, but is limited to high density objects as the x-rays render low-density soft tissues transparent. To address this issue, we explored a contrast-enhanced technique using a serial dehydration in ethanol and employing a chemical stain, specifically phosphotungstic acid (PTA), to image tendon using 3D micro-CT imaging. Utilizing this new contrast enhancing method, 3D images from tissues initially were analyzed and processed to identify and trace tendon fascicles and analyze the anatomical organization of immature (postnatal day 21) rat tails and hind limbs. From this analysis, we found that tail tendon fascicles appeared to cross between fascicle bundles, whereas it was previously assumed that the fascicle bundles maintain specific tracks within the rat tail tendons. Based on these initial findings, the objective of this study was to visualize the tendons in the tails and hind limbs of both younger and older, sexually mature rats to further validate our imaging technique and evaluate fascicle organization.

Results: The dehydrated and PTA-stained P21 and P50 tails and hindlimbs have clearly visible tendons and other soft tissues, providing additional evidence that this staining and imaging technique is applicable to younger and older (sexually mature P50) rats. Even with their much larger size and increased tissue density with age, PTA staining appears to be effective and penetrated the tissues and enhanced soft tissue contrast. Tendon fascicle organization was examined in both P21 and P50 tails. When viewing the P21 tails and moving from a more proximal to distal location, individual tendon sub-fascicles appear to move from one fascicle bundle to a neighboring fascicle bundle. However, the P50 tails appear to have tendon fascicles that divide into smaller subfascicles, moving from a more proximal to distal location. Tendon insertions in P50 tissue appear to follow a specific pattern of outer fascicle bundles moving to insert at the proximal side of the tail vertebra. Overall, validation of this imaging technique in both young and mature rats has allowed for tracking changes in tendon organization and structure with development. Coupling this contrast-enhancing technique with micro-CT scanning enables clear visualization of tendon and its organization and insertion sites, which advances future studies to determine tendon structure and organization in situ. Ultimately, better understanding of tendon structure-function relationships, including how they transmit mechanical forces, will improve treatment methods for restoring tendon function after an injury.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **William Auten**

Faculty Mentor: *Kristopher Waynant, Chemistry*

Project Title: *Design, synthesis, and redesign of therapeutic peptides using SPSS, native chemical ligation, and AutoDock Crankpep*

Abstract: The use of molecular modeling is quickly becoming an essential tool for the experimentalist. In this project, the molecular docking software AutoDock CrankPep (ADCP) will be utilized to analyze a variety of parameters on peptides to determine which parameters are the largest contributors in producing active compounds when synthesized experimentally and give higher accuracy to the computational results. Our hypothesis is that ADCP parameters (whose exactness we are trying to figure out) can be manipulated through inspiration from wet lab data to give scores more like real world values. This will then lead to faster, more efficient methods for the discovery of peptide-based drug/biologically active compounds.

Objectives: Protein-peptide interactions are among the most important interactions in living organisms. Peptides are essentially keys, or activators, that unlock specified functions of proteins. Many of these peptides are hormones. Proteins take on a variety of functions in cells, from structure to transport, from activating cell growth to causing cell death. For this project we will focus on SUMO1 (small ubiquitin-like modifier 1). SUMO1 is a post-translational modifier and is interesting due to its potential in fighting cancerous cell growth. SUMO1 is a well-studied protein and has known peptidic ligands. These peptides are of interest due to their potential therapeutic use. The benefit of a natural peptide as a drug is that peptide production could be induced through genetic therapies. Peptides are notoriously poor drugs when administered orally as most of our digestive system works to destroy peptides before they can enter the lumen. By identifying new natural peptides that bind to SUMO1 and inhibit cell growth, the project can then become a feedback loop that builds from the modeling and learns from the binding experiments to build a better peptide drug. Modeling is a very useful tool that can be used to reduce the amount of work for experimenters. AutoDock CrankPep has been praised for its efficiency and its ability to dock peptides with more residues than other docking methods. ADCP is a *de novo* method. This means that the conformation of the peptide is determined while docking (2). ADCP manages to be less computationally taxing and runs simulations faster than other *de novo* methods.

Conclusions: While this project is still ongoing, there are several advancements that were made over the summer, including gaining access and familiarity with the operation and maintenance of an Isothermal titration calorimeter (ITC), as well as an automated solid-phase peptide synthesizer. Several peptides were synthesized using the automated synthesizer, they were purified with high performance liquid chromatograph (HPLC) and characterized using electrospray ionization mass spectrometry (ESI-MS). Additionally, to create long peptides for this project I continued to advance my skills in a peptide to peptide linking strategy called native chemical ligation (NCL). In NCL, no protecting group is needed and simply requires a cysteine residue somewhere in the sequence. Progress was made and the synthesis of target molecules (connected peptides) was confirmed using mass spectrometry.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Peter Wieber**

Faculty Mentor: *Nathan Schiele, Biological Engineering*

Project Title: *Development of a Bioreactor to Mechanically Stimulate and Evaluate Cell Self-assembled Neotendons*

Abstract: Tendon injuries are common but current repair methods are inadequate. Even with surgical repair, scar tissue and incomplete tendon healing result in prolonged weakness which presents a risk for re-rupture. Thus, new regenerative treatment methods are required. To develop new treatments, mesenchymal stem cells (MSCs) have been explored in tissue engineering strategies to form tendon replacements. Much of the current research is focused on recapitulating adult tendon structure and function using biomaterial scaffolds, but tissue engineering approaches aimed at modeling embryonic tissue development may lead to a new understanding of tissue formation. Our lab has developed a tissue engineering method to guide MSCs to form neotendons through directed cell self-assembly, which appear to mimic the early highly cellular stages of embryonic tendon formation. However, maturation of these neotendons may be limited without the dynamic mechanical stimulation associated with *in vivo* muscle contraction. Applying mechanical stimulation is a unique challenge due to the delicate nature and small size of the neotendons. Thus, our objective was to develop a bioreactor system to mechanically stimulate the neotendons and assess how that stimulation alters cell morphology.

Results: From the cytotoxicity assay, day 1 of treatment with the VeroClear™(VC) resin extract media saw slightly more rounded cells in the media. However, by day 3 the differences between treatment and control diminished. Cell density appeared to decrease by a small margin when treated with the resin extract, but the resin would be classified as only slight cytotoxicity as described in ISO 10993-5:2009. Therefore, we deemed the VeroClear™(VC) as an acceptable material and used it to print the main body of the bioreactor chamber (Fig 1C). The bioreactor design meets the design criteria, connects to our prior system [1] and can apply dynamic mechanical loading to neotendons. Additionally, despite their small size (~6 mm long) and fragile nature, the neotendons withstood the process of mounting, gripping, and applying 1% tensile strain. Staining demonstrated that 24 hours after a loading cycle, cells in the neotendon maintained a cohesive structure. No differences were detected between loaded and static controls, and future work will explore higher loading magnitudes and longer timepoints. There are a few suggestions for future work as well including increasing the time of pre-culture or treating the neotendons with a tenogenic factor such as TGF-β2 before applying loading. Lastly, some warping of the bioreactor occurred with multiple ethanol sterilization cycles suggesting that an alternative method (e.g., autoclaving) should be explored to increase the lifespan of the 3D resin-printed parts. In conclusion, we developed and tested a bioreactor system that can successfully apply mechanical stimuli to a cell-self assembled neotendon. Using this system, we can better understand how mechanical tensile loading impacts the early stages of tendon tissue formation *in vitro*.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Jennie Tafoya**

Faculty Mentor: *Robert Rinker, Electrical Engineering*

Project Title: *Tower of Lights Wireless Edition*

Abstract: Small, compact, and powerful, hardware Arduinos are microcontrollers that enable a user to more easily interact with the software utilized in many everyday applications. The unique functionality that the Arduino possesses is the ability to run a multitude of actions and processes synchronously, opening opportunity to perform a variety of processes otherwise difficult to handle on one controller. With the way that the microcontroller's interface is built, it allows those working on the Arduino to work closely with embedded systems. In my project, I plan to further study and exercise the processes that the Arduino can handle, expanding the capability to mass wireless functionality for the purpose of ease of reliable entertainment display in our Vandal Homecoming's Tower of Lights light show. Between the integrated development environment and multi-functional controller, the Arduino enables fluid study between hardware and software components. This summer, I plan to work closely with Dr. Rinker to improve my knowledge and solidify the bridge between the hardware and software world to create a product that envelopes user friendliness with wireless functionality.

Objectives: To expand TowerLights show from Fall 2022 with a completely wireless setup for Fall2023. The Tower of Lights operates by using mechanisms called "light bars". These are LEDs attached by aluminum wire to a microcontroller, all taped onto a wooden beam with a notch running down the middle for wire to run through. There are forty beams made for all forty rooms of the south-facing windows of the Theophilus Tower, between the 2nd and 11th floors. The wireless setup for the TowerLights show involves using Zigbee's Xbee Pro wireless transmitter, modeling the set up utilized for the Vandal Marching Band's LED glasses performances. Rather than using the connections made in the network closet on each floor from a plug-in to the wall, the idea for wireless is to provide portability. By attaching its power source to the beam, the LED circuit can be used in virtually any location.

Conclusions: With my project, I am happy to exclaim that I created a working prototype for the wireless edition of the Tower of Lights. To do this, I had to re-design the circuit involved between the power source, the microcontroller, and the LEDs. With the wired circuit set up, the power was drawn from a bigger power source. With the wireless setup, the power supply was limited to a nine-volt battery, which hindered the emission of light from the LEDs. The green and blue component of the LEDs required a minimum of 3.2 volts to light up each LED. With three LEDs in series, 9 volts simply wasn't enough. To counteract this problem, I studied and analyzed the distribution of power throughout the circuit set-up and concluded that a parallel circuit would deliver enough power without having to make any major changes to the circuit board that the microcontroller sits on. However, with three LEDs, the parallel circuit was lop-sided and may have involved extra resistance to distribute the luminous intensity evenly. By adding another LED, the parallel circuit balanced out. Once the circuit was designed, I soldered it together, taped, and tested it extensively.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks. Supplies were purchased at \$955.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Juwon Elelu**

Faculty Mentor: *Herbert Hess, Electrical Engineering*

Project Title: *Reaped electromagnetic energy*

Abstract: Radio Frequency (RF) can be said to be a collective term for electromagnetic energy. This form of energy is derived from electromagnetic radiation which travels through a space between transmission antenna and receiving antenna. The receiving antenna only captured a small amount of RF energy. The purpose of this research is to design and build a system that can harvest the unused RF energy and convert it to useful electricity. We are surrounded by lots of devices that use RF energy in our day-to-day activities. Such devices include mobile phones, remote controls, microwaves, Wi-Fi, radio transmission towers etc. Most of these devices make use of batteries as a source of energy or as backup energy. These batteries are changed from time to time. The used batteries are disposed of in such a way that they cause environmental pollution. So, the need for alternative sources of energy for powering these devices cannot be overemphasized.

Objectives: Reaped electromagnetic harvester was designed to collecting unused RF radiation from its surroundings and convert AC to DC power. The project consisted of the following segments:

- **Transmission antenna:** The antenna responsible for collecting the radio frequencies. A patch antenna was decided for this project because they are small and flat allowing them to fit easily with circuit boards. The antenna collects energy at radio frequencies of 2.4GHz and uses the microstrip feedline as a feeding method. FR4 epoxy was used as the dielectric substrate for the patch antenna.
- **AC to DC converter:** Schottky diodes are responsible for collecting the AC current from the reaped RF energy at the antenna and converting into the DC current responsible for powering the device.
- **Microcontroller:** The microcontroller is responsible for collecting the DC current produced by the converter and performing the given task. The task given was to sense the amount of power passing through into a capacitor and once it had reached a certain amount it would stop the flow of current with the aid of a transistor, until power was needed to be stored again termed: switch mode control.

Project Accomplishments: Reaped electromagnetic harvester was designed to achieve the goal of collecting unused RF radiation from its surroundings and converting it to DC power. I designed and simulated my antenna with the aid of HFSS software to determine which material would be most suitable to make the antenna. From there I proceeded to search for a Schottky diode suitable to convert AC to DC, then I proceeded to make my PCB to allow me to test the parts for DC using an oscilloscope. Results showed that we were getting DC as an output which was a success, but this also led to the discovery that the diode could filter output, thereby acting as a capacitor. It was unexpected but it played in our favor and saved us resources. I used an oscilloscope to determine whether we were successfully getting DC from our circuitry and the outcome was a success. As for the microcontroller I was able to program it to control external hardware which sets the basis for future work. There is room for improvement for both the device and me. I hope to finish the original program after better understanding the MSP430, from there I can combine all units of the device to make it whole and functional. From there I hope to include a sensor into the device to create room for more experiments. And as time goes by future researchers can try new things as well.

Summary of Budget Expenditures: \$6,000

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks. Unfortunately, as Juwon is not an American citizen, his \$5,000 stipend was taxed accordingly (30%) and he only received \$3,500.
- The student purchased consumables such as PCB boards, transistors, diodes, etc.
- The student printed a poster for \$100.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Katherine Ryssel**

Faculty Mentor: *James Van Leuven, Animal Veterinary and Food Sciences*

Project Title: *Usage of P. Larvae tailocins to treat American Foulbrood disease in honeybees*

Abstract: Tailocins are antibacterial proteins produced by some bacteria to kill closely related bacterial strains. In nature, this benefits the microbe by offering a way for them to control the bacterial composition of their environments. However, in a lab setting, researchers can use these tailocins to treat against unwanted bacteria. The purpose of this research project is to test whether a tailocin treatment is a viable option in protecting honeybees against the deadly American Foulbrood and European Foulbrood diseases, which are caused by the bacterial species *Paenibacillus larvae* and *Melissococcus plutonius*, respectively. To test this, the proposed research will involve three major parts over the course of the 10-week period. Collection and purification of tailocins from honeybee pathogens will occur over the first two weeks, in vitro analysis of tailocins against strains of *P. larvae* and *M. plutonius* will be completed by the fifth week, and in vivo treatment of infected bees by tailocins will be explored for the final 5 weeks. This work addresses the urgent need to develop novel antibacterials and reduce our dependence on traditional antibiotics.

Project Accomplishments: Of the seven *P. Larvae* strains which were tested, five showed tailocin-associated activity. Of those five, two had consistent and replicable results. Possible tailocin activity is considered when a sample creates a zone of inhibition on a bacterial lawn. This can be easily distinguished from the plaques created by a prophage. When diluted, a prophage sample would create multiple smaller plaques on the lawn. A bacteriocin (such as a tailocin) would not create individual plaques, and instead, diluted samples show a faded zone of inhibition resulting from a less efficient killing of bacteria in the area. This kind of activity was seen from strain 368W against 5 of the 7 strains. One of the strains it did not show activity against was itself, which was expected as producing strains are resistant to their products. Strain 25747 showed inhibitory activity against two strains, including one of the strains that 368W was ineffective against. 25747 also showed prophage activity against strain 2605. Additionally, other strains showed activity under certain conditions. Strains Y-3650 and 16425 both showed very light activity against 368W when lawns had very low bacterial concentrations. Strain 3670 showed activity against 4 or 5 other strains in two tests, but such activity has not yet been consistently replicable. Three samples were taken in for TEM imaging. Only two of these samples were clear enough to take pictures. Sample 368W had structures which somewhat resembled F-type tailocins but could be a virus. No tailocin-like structures were found in sample 3670, although some interesting structures were seen. Although samples 368W and 3670 were clear enough to take images, they were still very thick. In the future, a better method of isolation must be found prior to imaging. It may be important to find an imaging facility which has the capability to run a glow discharge on the copper grids. Glow discharge may prevent the clumping of certain charged molecules and therefore allow clearer images to be taken.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks. Katherine purchased \$1000 in supplies.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research
Grant – SURF 2023

Fellowship Recipient: Alyssa Livingston

Faculty Mentor: *Eva Strand / Courtney Conway, Natural Resources*

Project Title: *Northern Idaho Ground Squirrel Hypothesis Testing*

Abstract: Using ARCGIS and aerial imaging, I will compare changes in abundance of Northern Idaho Ground Squirrel populations to changes in forest canopy coverage over the past 50 years. I will also overlay these data to spatial footprints of past forest fires within areas that Northern Idaho Ground Squirrels inhabit. These comparisons will allow me to test the prevailing hypothesis for the population declines of this rare species: by testing the prediction that forest fire suppression has allowed tree growth and encroachment into the squirrel's habitat. This hypothesis predicts that the areas with the most pronounced population declines of Northern Idaho Ground Squirrels will have the most pronounced forest encroachment among colonies of Northern Idaho Ground Squirrels.

Project Accomplishments: Two main analyses were run on ArcGIS Pro: zonal statistics of change in tree cover over the past 40 years within the historical range of the Northern Idaho Ground Squirrel and within the squirrels' colony areas only. Results of the first test show that there has been an increase in tree cover in the historical range over the past 40 years. The effect size shows a 50% increase in tree cover through the entirety of the historical range. The tree cover in the historical range changes from 24% to 32% from 1986 to 2022 respectively, meaning that tree cover has increased in the historical range by roughly 8%. Results of the second test show that there has also been an increase in tree cover in the squirrels' colonies over the past 40 years. The effect size again shows a 50% increase in tree cover within extinct and extant colonies. The inhabited range of extant and extinct colonies shows tree cover changing from 7% to 9% from 1986 to 2022 respectively, meaning tree cover percentage has increased roughly 2% in the inhabited range in this time. The fire suppression hypothesis is supported based on two predictions. Forest canopy cover has significantly increased over the last 40 years in both the historical range of the Northern Idaho Ground Squirrel and in the explicit colonies within their range. Canopy cover within the historical range (15% cover) was higher than canopy cover within the actual colonies (5% cover). Experts on this rare species believe that these squirrels need areas with <15% canopy cover. The hypothesis is supported based on our results.

Future Research: I will be continuing this research as my thesis project for my degree. In the future I will be performing the same zonal analysis test on the colony range but split into two groups: extant and extinct. We would like to see if there is a correlation in extinct population areas and higher tree cover percentages. We would then like to do the same thing but use extant (stable or increasing) vs extinct + extant (decreasing). The population data that we have on this species is limited and spotty due to the nature of the squirrel and its hibernation patterns allowing only a small window for field data collection. We would still like to run a linear regression on the data we do have with our tree cover data to see if there is a correlation. We also hope to work with Idaho Fish and Game to get population data that is more conducive to our research to directly compare our data. Through my future research I plan to use more aerial imaging to determine more historic tree cover changes for extinct populations to determine whether there is a correlation. Most populations that are labeled as extinct were noted to be as such in the early 1980's, so I will be looking at aerial images from extinct colony areas and transporting them into ArcGIS Pro to get the zonal statistics and tree cover data for them for times further back than the Rangeland Analysis Platform can go (1986). We would finally like to get canopy cover data in corridors between colonies to see if there is ability for dispersal anymore or not.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.
- \$150 was spent on travel to Field Sites, \$75 was spent on creating a poster.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Mason Kilker**

Faculty Mentor: *Sebastian Stoian, Chemistry*

Project Title: *Synthesis and Structural Characterization of Zinc Complexes with N, S donor ligands.*

Abstract: Zinc complexes, which are diamagnetic with no unpaired electrons, are sought after for their unique chemical and biological applications as enzyme analogues or bioinspired catalysts, being relevant to several different areas in pathophysiology and bioinorganic chemistry. These potential applications require an understanding of the structural factors that lead to the desired properties of these compounds. The main goal of this proposal is to prepare a novel series of zinc complexes and to elucidate their coordination modes and structures both in solution, by NMR, and in solid state by x-ray crystallography. These complexes will incorporate a tetradentate ligand with N,S donor atoms, either S,S'-bis(2- pyridylmethyl)-1,2-thioethane (**bpte**) or S,S'-bis(2-pyridylmethyl)-1,3-thiopropene (**bptp**), and two additional anionic co-ligands NCX-, where X= O; S; Se; and BH₃. Because zinc complexes with **bpte** and **bptp** are virtually unexplored, this work will provide access to a large selection of zinc compounds with several diverse structures and will contribute to a greater understanding of steric factors at play in zinc complexation.

Project Accomplishments: We have synthesized and structurally characterized three new complexes, Zn(bpte)(NCS)₃, [Zn(bpte)(EtOH)₂](ClO₄)₂, and Cu(bpte)₂. The solid-state structures of these compounds were elucidated using X-ray crystallography. In addition, a previously synthesized complex, Zn(bpte)(NCBH₃)₂, was examined using Nuclear Magnetic Resonance (NMR) spectroscopy. Finally, we have optimized the synthetic protocol used to obtain Zn(bpte)(NCBH₃)₂. The bpte and bptp ligands were successfully synthesized using procedures adapted from published methods. Their structures and sample purities were assessed using nuclear magnetic resonance (NMR) spectroscopy. However, we have only explored the coordination chemistry of bpte. [Zn(bpte)(NCS)₂]. A new complex, [Zn(bpte)(NCS)₂], was synthesized. The structure of this compound was elucidated through X-ray crystallography. The complex was obtained as clear block crystals and exhibits a slightly distorted octahedral geometry. N-Zn-S angles are approximately 76 degrees (76.4°, 76.7°), and axial N atoms exhibit an angle of 167.7°. The experimental structure is shown in Figure 1 together with the model included in the proposal.

Over the summer of 2023, I was fortunate enough to take part in one workshop and one conference. I attended the Whitworth X-Ray Crystallography Workshop at their Spokane campus, where some basics of X-ray crystallography were covered. Additionally, I was able to present at ICUR in conjunction with my fellow undergraduate researchers.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.
- Spent \$703 on solvents, reagents, and characterization.
- Workshop Registration was \$225.

Acknowledgement: This student's poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – SURF 2023

Fellowship Recipient: **Zaiden Espe**

Faculty Mentor: *Frank Gao, Mathematics and Statistical Science*

Project Title: *Optimizing the Nelder-Mead method via Genetic Programming*

Abstract: This project aims to discover related methods and optimizations to the Nelder-Mead method. The Nelder-Mead method is an algorithm used to solve the unconstrained minimization problem, or function optimization problem that transforms a geometric object throughout the function space. To explore the limits of the Nelder-Mead method, genetic programming will be used. Genetic programming is the most robust approach because it will allow me to search a large space of modifications to the Nelder-Mead algorithm. The research will focus on adjusting the scalar parameters and reflections of the Nelder-Mead transformations. The result will be an algorithm based on the Nelder-Mead method. The expected outcome will exceed the standard Nelder-Mead method and variations.

Objectives: To test the frequency of selection of various reflection vectors in a copy of the comparison Nelder-Mead algorithm. The reflection vectors were called the “rank”, “inverse gradient”, “slope”, “evaluation”, “mirror”, and “top rank” reflections. Each of these vectors would be calculated at each iteration. Then the resulting vector was used as the centroid is used in the standard Nelder-Mead method to calculate the reflection. The rank vector was calculated using a weighted average of the n-best points in the n-dimensional simplex, with better ranked points having a linearly higher weight than worse points dependent on their rank. The inverse gradient vector was calculated by multiplying the inverse of the matrix generated by subtracting the worst vector from each vector in the simplex with the vector generated by subtracting the evaluation of the worst vector from the evaluation of the other vectors. This final vector gives an estimate of the gradient at the worst point that becomes more accurate as the simplex shrinks. The slope reflection is calculated by finding the slope from the worst point to each other point in the simplex, and then multiplying the new slope vector by the matrix formed by the difference of each vector and the worst vector. The evaluation reflection was calculated by using a weighted average of the n-best points in the simplex. The weights were determined by taking the square root of the difference between the function evaluation of the point and the function evaluation of the worst point. The mirror reflection was calculated by orthogonally projecting the worst vector through the space determined by the n-best vectors. The top rank reflection was formed by taking the rank average, but only with the top n/2-best vectors. Each reflection was tested as the replacement for the centroid vector in the standard Nelder-Mead method. The reflections were also tested in various combinations with each other, and all together, each being evaluated by the algorithm and then the best performing reflection chosen as the reflection. The algorithm was tested with n+k points, k being two or larger. The standard Nelder-Mead algorithm uses n+1 points. For values of k, the algorithm would reflect k-points, using the n-best points to determine the reflection. The value of two for k was tested most extensively. The tests compared how which reflections were chosen for each reflected vector by rank and how the reflections were manipulated via expansion, contraction, or standard reflection.

Results: The most successful algorithm used the standard reflection and mirror reflection with a simplex containing n+2 points. The worst point was always reflected using a mirror reflection except every ten iterations the standard reflection was used, and the second worst point was always reflected using a standard reflection.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement: Poster can be found in Appendix 1

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – Summer OUR Students’ 2023

Fellowship Recipient: **Kendall Mitton**

Faculty Mentor: *Bert Baumgaertner*

Project Title: *Anxiety and the Effectiveness of Fact-Checking*

Abstract: As levels of misinformation rise in the United States, so does the threat to efficient and effective policymaking. Most Americans are misinformed about a variety of topics and actively think and behave against the recommendations and empirical findings of experts. That said, the lack of fact-checking misinformation and failure to accept corrective information has fostered a variety of different problems within our borders (e.g., Qanon/PizzaGate). Anxiety may be a factor in this phenomenon, but it has been largely overlooked in previous research. Building off existing scholarship surrounding these variables, I will conduct an online survey experiment to test the relationship between anxiety and the effectiveness of fact-checking misinformation. The results of this survey will help further our broader understanding of the effect anxiety has on our behavior, as well as when fact-checking misinformation is effective. If society can identify when and how to effectively provide fact-checks, we may be able to minimize the threat misinformation poses to our Democracy.

Objectives: Many scholars have already conducted experiments on the manipulation of information exposure. Most notable for my research is the work of Albertson & Gadarian (2015) and Nyhan & Reifler (2018). Albertson & Gadarian (2015) identify several effects anxiety can have on the information we seek out and the information we are provided with. Furthermore, Nyhan & Reifler (2018) identify ways in which fact-checking effectively works to correct misinformation and misperceptions. While the findings of both these studies provide important knowledge on information exposure, there is a gap in this research that should be further explored. Moreover, the gap I want to bridge is between the types of information/opinions individuals maintain and how or when individuals assimilate new information. Strictly speaking, what effect does anxiety have on the effectiveness of fact-checking misinformation? It is important to fill this gap in our knowledge so that social and political experts will be in a better position to address issues related to misinformation.

Results: To properly identify the relationship between anxiety and misinformation fact-checks on Covid-19 vaccine opinions, I conducted an interaction data analysis. Using an interaction analysis, I was able to look at the interaction of my treatment and control groups for both independent variables on my dependent variable. Put simply, I was able to examine the four following groups: Control = {anxiety control/fact-check control}, Anxiety Dummy = {anxiety treatment/fact-check control}, Fact-Check Dummy = {anxiety control/fact-check treatment}, and the Interaction = {anxiety treatment/fact-check treatment}. Given my research was not focused on the interaction of two control groups, the following results will summarize the interaction of an Anxiety Dummy, a Fact-Check Dummy, and an Interaction. Regarding the Anxiety Dummy variable (i.e., the variable examining respondents in the anxiety treatment/fact-check control group), I found that anxiety has a significant but negative effect on a respondent’s individual perceptions about the Covid-19 vaccine. As one can see in the first row of the table, a 1-point increase in the respondent’s level of anxiety leads to a .35-point decrease in that individual’s perception towards the Covid-19 vaccine. In short, as a respondent’s anxiety level increases, the more negative their thoughts about the vaccine will be. Moving forward, I did not find any significant effect of the Fact-Check Dummy variable (i.e., the variable examining respondents in the anxiety control/fact-check treatment group) on individual perceptions about the Covid-19 vaccine. Similarly, I did not find any significant effect of the Interaction variable (i.e., the variable examining respondents in the anxiety treatment/fact-check treatment group) on individual perceptions about the Covid-19 vaccine.

Summary of Budget Expenditures: The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement: This student’s poster can be found in Appendix 2.

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – Summer OUR Students’ 2023

Fellowship Recipient: **Alexandro Aguilar**

Faculty Mentor: *Roger McVey*

Project Title:

Abstract: The purpose of this project is to research, perform, and analyze the piano music of Manuel Maria Ponce and study the influence of Mexican folk music on it, while exploring my own Mexican heritage. My goal is to highlight Ponce as a composer of an underrepresented background by performing his music at two different concerts, one of which I will oversee planning and organizing. The music of Mexican composers such as Ponce, deserves to be in the standard repertoire of classical piano as his artistic merit could be compared to that of other European composers such as Frederic Chopin or Maurice Ravel. It is important to highlight music from people of color and help expand the scope of music as a studied form of art if the study of classical piano were to stay relevant in modern day. I will do this by conducting research study on Ponce’s life, influences, and music. I will be showcasing the compositions of Manuel Ponce while bringing awareness to the music of composers from non-euro-centric backgrounds.

Project Accomplishments: From reading on Manuel Ponce’s life, analyzing his works for solo piano, and researching the music of Mexico, I found that the traditional folk genres of Mexico had a heavy influence on the compositional style of Manuel Ponce. The Jarabe, Cuban Contradanzas, Sons and Huapangos, and Corridos, all have heavy correlation from their musical motifs to those found in the compositions of Manuel Ponce. Ponce drew inspiration from the rhythmic motifs of these folk genres. There is a musical idea called a “Sesquialtera” that is found in both the music and dance of Mexico. The Sesquialtera is the flexibility between ternary and binary based rhythmic ideas. Manuel Ponce uses the Sesquialtera in an obvious manner in his works Scherzino Mexican and the B sections of the Cuatro Danzas Mexicanas, giving his works a dance topic derived from the rhythmic motifs. Ponce draws melodic inspiration from the traditional corridos that came from the Mexican Revolution which occurred during his early years as a composer. Ponce draws inspiration from the parallel third voicings of corrido melodies and the motific descending diatonic thirds that resolve phrases. He uses this in his Scherzino Mexicano and Romanza De Amor.

I plan to present my work done this Summer in the form of a lecture recital at the Lionel Hampton School of Music in September during Latinx Heritage Month. I will present the music SURF Grant Proposal of Mexico and the life and compositions of Manuel Ponce in the form of a lecture followed by a performance of the works I worked on by Ponce. I also plan on auditioning/applying to present the same work at the Music Teachers National Association National Conference in March of next year. I plan on continuing to research these topics while also learning and performing the works of Manuel Ponce for other events such as my junior and senior performance recitals.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement:

- This student’s poster can be found in Appendix 2
- This student’s poster won a 3-minute presentation competition held at UI on the eve of ICUR 2023.

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – Summer OUR Students’ 2023

Fellowship Recipient: **Amara Bailey**

Faculty Mentor: *Dr. Omi Hodwitz*

Project Title: *Missing and Murdered Indigenous Women, Girls, and Two-Spirit (MMIWG2) database*

Abstract: The United States and Canada have histories littered with abuse against Indigenous populations. The systemic racism which previously justified genocide and displacement of these communities is upheld today and felt throughout Indigenous communities. The devaluing of Indigenous lives is felt most notably by the epidemic of Missing and Murdered Indigenous Women, Girls, and Two-Spirit individuals (MMIWG2). Underlying this issue is an information deficit surrounding the thousands of cases that exist across Indigenous communities. The MMIWG2 database aims to resolve this problem by being an exhaustive culmination of already existing data from community-led efforts. The MMIWG2 database research involves the collection of MMIWG2 cases, and subsequent authentication of everyone’s case.

Project Accomplishments: This summer, approximately 500 cases of MMIWG2 in the United States were coded. Of those 500, only 407 were confirmed and authenticated. The data collected thus is representative of approximately 10% of the collected potential cases. The use of this data to understand the MMIWG2 epidemic would be irresponsible and paint an incomplete picture of the phenomenon. However, the data currently available is valuable in understanding who MMIWG2 are, the demographics of their offenders, as well as a basic understanding of the effectiveness of law enforcement in closing MMIWG2 cases. Of the total confirmed cases, 392 have known ages. Of these, 94 MMIWG2 were under 18 at the time of their victimization. Overwhelmingly, MMIWG2 identify as female. 405 confirmed cases have known genders, of which, 269 are female, 134 are male, 1 is non-binary, and 1 is two-spirit. Only 87 cases have identified at least one offender. Of these, 75 offenders are male and 3 were younger than 18 when they offended. The response by law enforcement in each case is incredibly variable. The role of tribal police is determined by the occurrence of an incident on tribal land; of the confirmed cases, 72, less than 20%, of incidents occurred on reservation. In terms of case resolution generally, there were only 364 cases with known outcomes. 54.7% of these are resolved, meaning an individual or their remains have been located. The remaining 45.3% of cases are still missing a body. Only 21.2% of total confirmed cases had both a known offender and a recovered body.

The data reveal a disturbing trend; many MMIWG2 cases are and remain unsolved. The significant failure to close these cases may be indicative of the ineffectiveness of law enforcement or poor reporting systems for MMIWG2. In many of the unconfirmed cases, no record of the individual existed. In almost all the confirmed cases, Facebook groups and other community-based reporting systems were heavily relied upon, as many individuals were not reflected in state-wide or federal databases. The continuation of investigation into this phenomenon is vital to understanding and eventually preventing the epidemic of MMIWG2. As the number of cases confirmed and coded increases, the data becomes more valuable and versatile. The data collected this summer only verify the intense need for continued research into an issue with almost no study or literature.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement: This student’s poster can be found in Appendix 2

Final Project Report: Office of Undergraduate Research (OUR) Undergraduate Research Grant – Summer OUR Students’ 2023

Fellowship Recipient: **Hunter Rouse**

Faculty Mentor: *Joshua Bailey*

Project Title: *Does Functional Power Threshold test differ between bikes*

Abstract: Advancements in technology have continued to push the limits on how cyclists optimize training programs based on intensity. Power measures provide instantaneous feedback reflective of each pedal stroke versus heart rate measures which possess a delayed response. A Functional Threshold Power (FTP) test to establish the average power output during a maximal effort ride is an effective tool to create intensity zones for training.¹ FTP tests are traditionally performed outdoors. However, with poor weather or limited routes, they can be performed indoors on stationary trainers. The Wahoo Kickr stationary cycle was designed to resemble a true road cycling experience while staying indoors. Prior to utilizing the Kickr as a tool for completing an FTP test, potential differences between the cyclist road bike and the Kickr need to be established. Therefore, the purpose of the study is to investigate if an individual’s performance during an FTP test is affected by the type of stationary bike. Cyclists will perform a 20-minute maximal effort FTP test on their personal bike and one on the Kickr stationary bike. It is hypothesized cyclist will have higher average power output when performing the FTP test on their own bike.

Summary of Budget Expenditures:

- The student was awarded a \$5,000 stipend to conduct this research for 40h/ week over 10 weeks.

Acknowledgement:

- This student was selected to give a 45-minute Paired Research Presentation with his mentor at the ICUR 2023 and did not present a poster.

Appendix 1

Determining the role of the TGFβ Type II Receptor on lysyl oxidase production

Dillon B. West, Colin R. Marchus, and Nathan R. Schiele

Department of Chemical & Biological Engineering, University of Idaho, Moscow, ID

Abstract

Tendons transfer forces from muscle to bone and are vital to movement. Unfortunately, tendons are injured frequently and have poor self-healing capability. Current therapies are unable to restore damaged tendons to their prior strength. Tissue engineering using mesenchymal stem cells (MSCs) is being investigated in strategies to develop functional tendon replacements or repairs. A current challenge is the limited information on the regulation of MSC differentiation into specialized tendon cells (tenocytes) and control of functional tendon formation. Prior work showed that the transforming growth factor beta (TGFβ) family of cytokines are critical in regulating tenogenesis and the production of lysyl oxidase (LOX), an enzyme that mediates collagen crosslinking and functional tendon formation. TGFβ may activate the TGFβ Type II Receptor (TGFβRII), a transmembrane protein that recruits and phosphorylates TGFβRI when bound by a TGFβ ligand. However, how TGFβRII signaling controls the TGFβ response in MSCs to regulate LOX production is unclear. The objective of this study was to determine how inhibition of TGFβRII impacts LOX levels in MSCs. We are exploring inhibiting TGFβRII using both a chemical agent as well as siRNA and evaluating the impacts on MSCs and LOX levels. The outcomes of these studies will show how TGFβ signaling through TGFβRII in MSCs regulates LOX levels, which can be used to direct functional tendon tissue formation and future regenerative therapies.

Background

- Tendons are connective tissues that absorb and transmit forces to allow body movement that injure easily and heal poorly
- The cytokine TGFβ is believed to be responsible for the expression of functional tendon markers such as lysyl oxidase (LOX)
- LOX is an enzyme that mediates the crosslinking of collagen in tendons
- There is a limited understanding of how the signaling pathways between TGFβ Type I and Type II Receptors may differ

Objective: Identify how TGFβ Type II Receptor impacts lysyl oxidase production

Experimental Design

- The role of TGFβRII can be investigated via inhibition methods
- Morin was found in literature to be a potential chemical inhibitor of TGFβRII
- However, there was little support and TGFβRII may have the ability to auto-phosphorylate
- RNA interference utilizing siRNA (short interference RNA) was selected as a secondary method to disrupt TGFβRII levels

Experiment 1: TGFβ Type II Receptor Chemical Inhibition

Methods & Materials

Figure 1: A schematic of the experimental design. Murine MSCs were treated with TGFβ2 and Morin. TGFβ2 was added at 1, 5, 10, 50, and 100 ng/mL. Morin was added at 0.5, 5, and 50 μM. Cells were imaged, collected at 1, 3, 7 days.

Morin may not impact LOX

Figure 2: A schematic of the experimental design. Murine MSCs were treated with TGFβ2 and Morin. TGFβ2 was added at 1, 5, 10, 50, and 100 ng/mL. Morin was added at 0.5, 5, and 50 μM. Cells were imaged, collected at 1, 3, 7 days.

Trial 1

50 μM

Trial 2

50 μM

Trial 3

50 μM

Figure 3: High concentrations of DMSO resulted in decreased cell morphology and cell death. Day 1, 3, 7, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100. Cells were imaged, collected at 1, 3, 7 days.

Figure 4: High concentrations of DMSO resulted in decreased cell morphology and cell death. Day 1, 3, 7, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100. Cells were imaged, collected at 1, 3, 7 days.

Experiment 2: TGFβ Type II Receptor siRNA Inhibition

Methods & Materials

Figure 5: A schematic of the experimental design. Murine MSCs were treated with TGFβ2 and siRNA. TGFβ2 was added at 1, 5, 10, 50, and 100 ng/mL. siRNA was added at 0.1, 1, and 10 nM. Cells were imaged, collected at 24 and 48 hours.

Fluorescent Control

14 Hours 44 Hours

TGFβ2 Treatment

0 Hours 24 Hours 48 Hours

Figure 6: The difference in morphology between the negative control and the siRNA negative treatment of TGFβ2. TGFβ2 treatment typically results in increased cell proliferation and more fibroblastic appearance. The negative control condition typical treatment TGFβ2.

LOX levels with siRNA and TGFβ2 treatment

Figure 7: A schematic of the experimental design. Murine MSCs were treated with TGFβ2 and siRNA. TGFβ2 was added at 1, 5, 10, 50, and 100 ng/mL. siRNA was added at 0.1, 1, and 10 nM. Cells were imaged, collected at 24 and 48 hours.

Discussion & Future Directions

The observed cell morphology differences between morin and in vehicle control are negligible. The cell morphology differences between the siRNA construct and the negative control suggest a more thorough inhibition of TGFβRII. In the future, additional siRNAs and siRNA knockdowns will be analyzed to quantify the levels of SMAD activation and LOX protein levels to better understand the role of TGFβRII.

Acknowledgements

This project was supported by the Office of Undergraduate Research, the Summer Undergraduate Research Fellowship program, NSF Grant #2145064, and the INBRE Program, NSF Grant No. 220 GM013408 (National Institute of General Medical Sciences).

Precision Agriculture Adoption and Integration Case Study

Lacey Hunt, Dr. John Shovic, Mary Everett, Garrett Wells, Walter Neils

DEPARTMENT OF COMPUTER SCIENCE, UNIVERSITY OF IDAHO

Introduction

- Precision agriculture describes a variety of emerging technological systems and tools for use in crop and livestock farming
- Improve profitability for farmers [1]
- Potentially reduce negative climatic impacts of farming [2]
- Remote sensing is a tool that has not been widely adopted, despite availability of these systems [3]
- This is due to high cost and lack of usability
- Sensor Collection and Remote Environment Care Reasoning Operation (SCARECRO) system
- Modular, extensible, open-source system that uses low-cost hardware to resolve cost and usability issues
- Consists of a gateway, middle agent, webserver, and sensors
- Send data collected by sensors to database to be stored, displayed, and used in AI models
- Already implemented in Laurel Grove Wine Farm in Winchester, VA
- This project aims to test this system's performance in a new application domain: a heritage apple orchard at Sandpoint Organic Agriculture Center (SOAC)
- Observe performance, compare cost, and evaluate usability

Methods

- Performance
- Perform routine system maintenance and determine uptime
- Write automated tools in Python to find system faults
- Cost
- Calculate labor and component implementation cost
- Compare to other similar remote sensing systems
- Usability
- Integrate dashboard to display relevant data
- Regularly survey farmer regarding system functionality

Progress

- Assembly and installation of all system components is complete (Figure 2)
- Gateway to eliminate duplicate messages, keep track of sensor connections, and send data to the database
- Aggregator (Datagator) to collect and transmit readings from sensors located further away from the gateway
- WeatherRack (both WR2 and WR3 models used) to collect weather data
- Middle agent to handle data transmission to gateway and/or database on cloud computer
- Integration of a dashboard to view collected data from database (Figure 3)
- System usage and usability surveys
- Conducted virtually over a 10-week period (will start late summer)
- Used to discover the usability of the system and dashboard as well as ask for suggestions to improve the system in the future
- Began cost analysis of current structure and comparison to similar systems

Results

- Performance
- System assembly and implementation was successful
- Consistent data coming in
- Occasional continuous network connectivity issues
- Preliminary research showed financial advantage to using SCARECRO as compared to other similar systems
- Initial discussions with horticulturalists at SOAC proved this system's usefulness and room for input

Future Work

- Conduct and analyze continued farmer surveys
- Implement SOAC horticulturalist suggestions
- Light canopy sensors to quantify benefits of pruning
- Degree day modeling for pest control
- Installation of additional local test unit (Harbor Center)
- Help test reliability in a new setting
- Troubleshoot connection issues in gateway

References

[1] M. Boehlje. (2021, February 22) The Value of Data/Information and the Payoff of Precision Farming. [Online]. Available: <https://ag.purdue.edu/commercialag/home/resource/2021/02/the-value-of-data-information-and-the-payoff-of-precision-farming/>

[2] P. A. C. T. Force. (2021, November 10) Task Force for Reviewing the Connectivity and Technology Needs of Precision Agriculture in the United States. [Online]. Available: <https://www.fcc.gov/sites/default/files/precision-ag-report-11102021.pdf>

[3] Lowenberg-DeBoer, J., and Erickson, B. (2019, July 1). Setting the Record Straight on Precision Agriculture Adoption. Available: <https://eaccess.onlinelibrary.wiley.com/doi/full/10.2134/agronj2018.12.0779>

Acknowledgements

Thank you to Mary Everett, for her role as project lead and SCARECRO architect; Garrett Wells, for his design of the Datagator; Walter Neils, for his direction as the Dashboard lead of the Laurel Grove site; and Kyle Nagy, for his contribution as the SOAC Operations Manager and subject of human research. This project was funded thanks to an Office of Undergraduate Research SURF grant in the summer of 2023.

Learn more about me, my research project, and keep up with my future projects here:

SCARECRO System Current Communication Implementation

Figure 1: SCARECRO communication diagram

Figure 2: Left to right: Datagator, Gateway, WeatherRack Station

Figure 3: SOAC Dashboard

INFORMATIONAL - IRSA

TAB 1 Page 156

Segmentation analyses to identify and quantify microglia in 3D image stacks

¹UNIVERSITY OF IDAHO, ²LEWIS-CLARK STATE COLLEGE

³DEPARTMENT OF COMPUTER SCIENCE, ⁴DEPARTMENT OF BIOLOGICAL SCIENCES

Dan Blanchette¹, Dr. Samuel Seth Long^{2,3}, Dr. Diana Mitchell^{1, 4}

ABSTRACT

Using time-lapse confocal microscopy to record and observe microglia behavior in living zebrafish embryos, the Mitchell lab investigates the molecular basis of dynamic migration and phagocytic behavior of microglia in the central nervous system. Microglial cells regulate brain development, maintain neuronal networks, and repair neural injuries. Time-lapse imaging provides crucial insight into the behavior of these cells. Other methods, such as manual cell counting, are subject to human bias and are tedious, repetitive, and time-consuming. The Long computer science lab utilizes Python and open-source modules to develop an automated pipeline as a programmatic solution. These methods aim to expedite and optimize the lab's manual processes. This research project seeks to segment microglia when applied to 3D time series image stacks. Computer segmentation of microglia imaging relies on pixel values to generate bitmaps. Microglia segmentation is challenging because the cell's irregular shape and size can be obscured, resulting in omitted pixel intensity values. Two programs were developed to test the viability of Otsu, multi-Otsu, and Yen automatic thresholding[2]. Both methods separate the raw image into two layers: the foreground and background. Numerical data is generated via histograms to predict optimal threshold values for each algorithm. Prototype implementations of these programs demonstrate viability for microglia counting. However, misclassification of microglia occurs when the predicted pixel threshold is outside the histogram's range. Further refinement of these programs is crucial as they will be foundational for future object classification methods and microglia tracking, optimizing the lab's data processing capabilities and time.

INTRODUCTION

- Microglial cells regulate brain development, maintain neuronal networks, and repair neural injuries.
- Bit masking is the method of isolating specific color value combinations (objects of interest) from the rest of a digital image.
- Previous versions of this program were applied to 2D images with a set threshold value. The aim of this iteration is to adapt dynamic thresholding methods to 3D image stacks.



METHODS

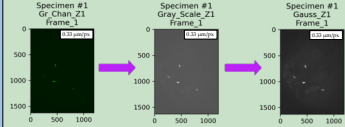


Figure 1: Copying of raw image with applied gray scale then Gaussian blur[1]. (NOTE: all images were recorded at 20x magnification)

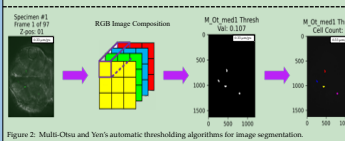


Figure 2: Multi-Otsu and Yen's automatic thresholding algorithms for image segmentation.

RESULTS

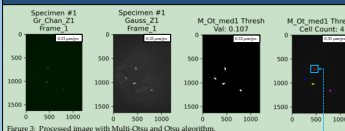


Figure 3: Processed image with Multi-Otsu and Otsu algorithm.

Frame	Area	Cell Count	Pixel Intensity	Threshold Value
1	1	1	100	100
2	2	2	200	200
3	3	3	300	300
4	4	4	400	400
5	5	5	500	500
6	6	6	600	600
7	7	7	700	700
8	8	8	800	800
9	9	9	900	900
10	10	10	1000	1000
11	11	11	1100	1100
12	12	12	1200	1200
13	13	13	1300	1300
14	14	14	1400	1400
15	15	15	1500	1500
16	16	16	1600	1600
17	17	17	1700	1700
18	18	18	1800	1800
19	19	19	1900	1900
20	20	20	2000	2000

Table 1: Multi-Otsu and Otsu results.

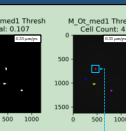


Figure 4: Mis-classified object.

RESULTS (CONT.)

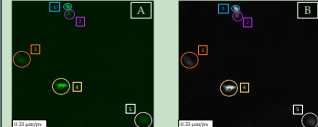


Figure 5A: Manual count of microglial cells.

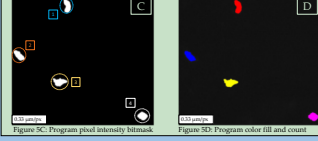


Figure 5B: Verification count with denoising.

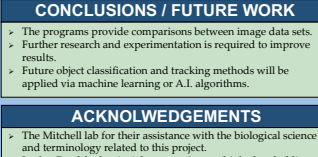


Figure 5C: Program pixel intensity bitmap.

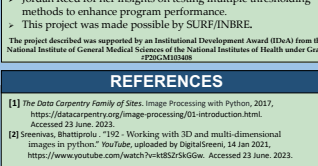


Figure 5D: Program color fill and count.

CONCLUSIONS / FUTURE WORK

- The programs provide comparisons between image data sets.
- Further research and experimentation is required to improve results.
- Future object classification and tracking methods will be applied via machine learning or A.I. algorithms.

ACKNOWLEDGEMENTS

The Mitchell lab for their assistance with the biological science and terminology related to this project.
Jordan Reed for her insights on testing multiple thresholding methods to enhance program performance.
This project was made possible by SURF/INBRE.
The project described was supported by an Institutional Development Award (IDeA) from the National Institute of General Medical Sciences of the National Institutes of Health under Grant #P20GM110340.

REFERENCES

- [1] The Data Carpentry Family of Sites. Image Processing with Python, 2017, <https://datacarpentry.org/image-processing/01-introduction.html>. Accessed 23 June, 2023.
- [2] Sreenivas, Bhattiprolu. "192 - Working with 3D and multi-dimensional images in python." YouTube, updated by DigitalSreen, 14 Jan 2021, <https://www.youtube.com/watch?v=K5E52gkG0w>. Accessed 23 June, 2023.

Visualization of tendon organization and fascicle crossover in 3D using micro-CT

University of Idaho

Destinee M. Ditton¹, Colin R. Marchus¹, Michele R. Brumley², and Nathan R. Schiele¹

¹Department of Chemical & Biological Engineering, University of Idaho, Moscow, ID, ²Department of Psychology, Idaho State University, Pocatello, ID

IdahoINBRE

Abstract

Micro-computed tomography (CT) is an x-ray-based imaging modality that produces three-dimensional (3D), high-resolution images of whole-mount tissues, but is limited to dense tissues, such as bone. The x-rays readily pass through tendons, rendering them transparent. Contrast-enhancing chemical stains have been explored, but their use to improve contrast in tendon for micro-CT imaging had not been systematically evaluated. To address this, our previous investigation showed that phosphotungstic acid (PTA) staining increased x-ray absorption of tendons to enhance tissue contrast and obtain 3D micro-CT images of rat tendons within the tail and hindlimb. Further, we demonstrated that tissue hydration state significantly impacts soft tissue contrast. Utilizing this new contrast enhancing method, 3D images from tissues were analyzed and processed to identify and trace tendon fascicles and analyze the anatomical organization of the tail and hindlimb. From this analysis, we found that tail tendon fascicles appeared to cross between fascicle bundles, whereas it was assumed that the fascicle bundles maintain specific tracks within the tendon. Based on these initial findings, we extended our study and investigated the tails and hindlimbs of younger and older, sexually mature rats to evaluate tendon fascicle crossover as a function of age. Ultimately, contrast-enhanced 3D micro-CT imaging will lead to better understanding of tendon structure, and relationships between the bone and soft tissues.

Background

- Tendons are connective tissues that absorb and transmit forces to allow body movement that injure easily and heal poorly
- Need to understand structure-function relationships with comprehensive imaging
- Soft tissues are difficult to visualize *in situ*
 - Using a micro-CT scanner allows 3D visualization of tissue, but requires high density materials
- Phosphotungstic acid (PTA) stains collagenous tissues for observation with micro-CT
- Identified most effective contrast-enhancing technique for micro-CT imaging of tendon

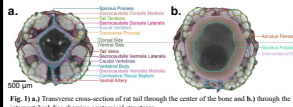


Fig. 1: a) Transverse cross-section of rat tail through the center of the bone and b) through the intervertebral disc showing anatomical structures.

Objective: Validate a contrast-enhancing imaging technique for a range of ages and evaluate structural changes in the tendon with development

Methods and Materials

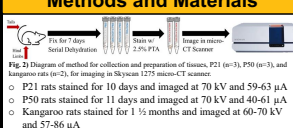


Fig. 2: Diagram of method for collection and preparation of tissues, P21 (n=3), P50 (n=3), and kangaroo rats (n=2), for imaging on Skyscan 1275 micro-CT scanner.

Imaging technique allows for comparison of skeletal development

1. Dehydrated, Stained P21

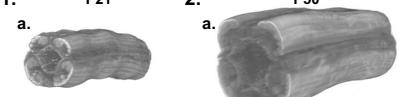


Fig. 3: 1-2, a) Three dimensional images of rat tail midsection. 1-2, b) Images of sagittal tail cross-sections through the center. 1-2, c) Images of transverse tail cross-sections through the center of the bone (left) and the start of the end plate (right). 3-4, a) Three dimensional images of rat hindlimbs. 3-4, b) Sagittal cross-section of hindlimb.

2. Dehydrated, Stained P50



Fig. 3: 3-4, a) Three dimensional images of rat tail midsection. 3-4, b) Images of sagittal tail cross-sections through the center. 3-4, c) Images of transverse tail cross-sections through the center of the bone (left) and the start of the end plate (right). 5-6, a) Three dimensional images of rat hindlimbs. 5-6, b) Sagittal cross-section of hindlimb.

3. Dehydrated, Stained P21

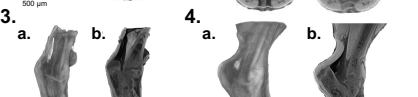


Fig. 3: 5-6, a) Three dimensional images of rat tail midsection. 5-6, b) Images of sagittal tail cross-sections through the center. 5-6, c) Images of transverse tail cross-sections through the center of the bone (left) and the start of the end plate (right). 7-8, a) Three dimensional images of rat hindlimbs. 7-8, b) Sagittal cross-section of hindlimb.

4. Dehydrated, Stained P50

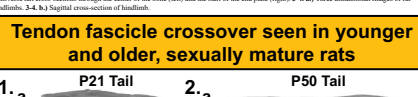


Fig. 3: 7-8, a) Three dimensional images of rat tail midsection. 7-8, b) Images of sagittal tail cross-sections through the center. 7-8, c) Images of transverse tail cross-sections through the center of the bone (left) and the start of the end plate (right). 9-10, a) Three dimensional images of rat hindlimbs. 9-10, b) Sagittal cross-section of hindlimb.

Tendon fascicle crossover seen in younger and older, sexually mature rats

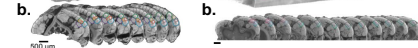


Fig. 4: 1-2, a) Dehydrated, stained tail segment with hand-drawn fiber tracing from surface of tissue and 1-2, b) through transverse cross-section throughout the length of the rat tail. 1 runs proximal to distal, while 2 runs distal to proximal.

Tendon insertion pattern visible in tails

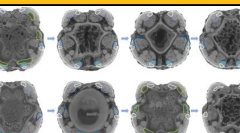


Fig. 5: Pattern of tendon insertion in P50 (running from proximal to distal end). Inserting tendons are outlined in blue; insertion sites in green, and the next set of inserting tendons in white.

Discussion & Conclusion

- Bone calcification and tissue growth seen in age comparison
- Tendon crossover seen in both P21 and P50, however, yet to see tendon fascicles joining different bundles in P50
- Within tail, tendons insert into bone in a specific pattern
- New procedural findings, including stain stability and skin removal impact on stain penetration

Further Applications

- Implications of method development includes:
 - Fascicle/fiber tracing across length of sample
 - Examination of tendon development across age groups
 - Analysis of tendons in different species/genotypes
 - Examination of other animals/rat species anatomy
 - Analysis of kangaroo rat musculoskeletal system and tendon organization/attachment

1. Dorsiflexion 2. Plantar Flexion

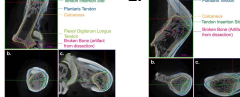


Fig. 6: 1-2, a) Dehydrated, stained kangaroo rat hindlimb transverse cross-section. 1,2, b) frontal cross-section, and 1-2, c) sagittal cross-section displaying anatomical structures.

Acknowledgements

This project was supported by the M.J. Murdock Charitable Trust (micro-CT scanner), the University of Idaho Office of Undergraduate Research - SURF, and an Institutional Development Award (IDeA) from the National Institute of General Medical Sciences of the National Institutes of Health under Grant #P20GM110340.

Design, synthesis, and redesign of therapeutic peptides using SPSS, native chemical ligation, and AutoDock Crankpep

William Auten^{1,2}, Matt Womelduff², Kristopher Waynant¹, F. Marty Ytreberg², Darren A. Thompson^{1,3}



¹Dept. of Chemistry, University of Idaho, ²Dept. Of Physics, University of Idaho, ³Peptidaho Research Consortium



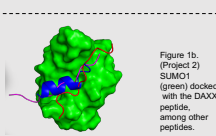
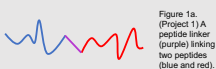
Abstract

The use of molecular modeling is quickly becoming an essential tool for the experimentalist. In this project, the molecular docking software AutoDock CrankPep (ADCP) was utilized to analyze a variety of parameters on peptide sequences to determine which are the largest contributors in producing active compounds when synthesized experimentally and which provide the most accuracy to the computational results. Our hypothesis is that ADCP parameters (whose exactness we are trying to figure out.) can be manipulated through inspiration from wet lab data to give scores more similar to real world values. This will then lead to faster, more efficient methods for the discovery of peptide-based drugs / biologically active compounds.

Introduction

Two Projects (Figure 1).

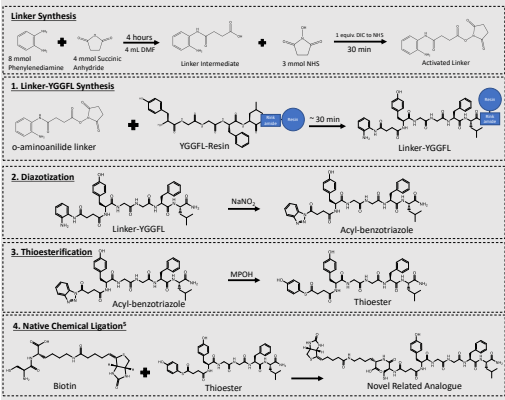
- Project 1:** Linking peptides utilizing native chemical ligation and a novel peptide linker.
 - Resulting dipeptide has two C-Terminal.
- Project 2:** Devise peptide modeling method for ADCP.
 - Current ADCP runs produce data that strays from *in situ* data.



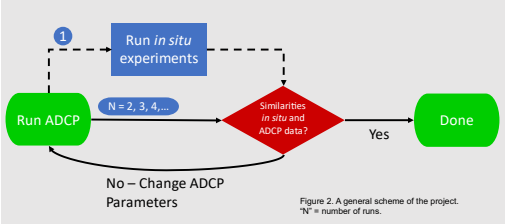
Acknowledgments

Thank you to Lee DeBard and the Moore-Speer Center for help with analysis. The project described was supported by an Institutional Development Award (IDeA) from the National Institute of General Medical Sciences of the National Institutes of Health under Grant #P20GM103408.

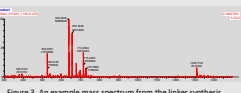
Project 1 Methods – Linker Synthesis and Native Chemical Ligation



Project 2 Methods – SUMO1, AutoDock CrankPep, and Peptide Docking



Project 1 Results



Project 2 Results

Region	Best Score	# of Steps	Best Score	# of Steps	Best Score	# of Steps
Region 1	-1.2	10	-1.2	10	-1.2	10
Region 2	-1.2	10	-1.2	10	-1.2	10
Region 3	-1.2	10	-1.2	10	-1.2	10
Region 4	-1.2	10	-1.2	10	-1.2	10
Region 5	-1.2	10	-1.2	10	-1.2	10
Region 6	-1.2	10	-1.2	10	-1.2	10
Region 7	-1.2	10	-1.2	10	-1.2	10
Region 8	-1.2	10	-1.2	10	-1.2	10
Region 9	-1.2	10	-1.2	10	-1.2	10
Region 10	-1.2	10	-1.2	10	-1.2	10

Figure 4: Comparison of several ADCP runs. The header of each column describes tested parameters of the run, these being the number of replicates and the number of Monte Carlo steps. The green highlights in the "Sequence" column represents residue mutations of the wildtype (DAXX), represented in the first row. The yellow and red highlights accentuate the highest and lowest affinity of each set of parameters/column respectively.

Discussion

- Current Work:**
- Currently generating *in silico* affinities using ADCP
 - Currently collecting chromatograms and mass spectra for the peptide linker project
- Future Work:**
- Will use SPSS to synthesize peptides in ADCP work, then ITC to generate experimental binding affinities
 - Finish collecting characterization data
 - Finish collecting docking affinities *in situ* and *in silico*
 - Compare *in silico* and *in situ* docking affinities and run different parameters to possibly determine which parameters allow for more accurate binding predictions

Work Cited

- (1) Targeting SUMO Signaling to Wheatle Cancer. J. K. Koonen, 1 and A. H. C. O. Thompson.
- (2) Chaperone P. A. Best, M. J. Ford, D. T. Swales, A. P. Hinton, J. C. J. Thompson, D. A. Chaperone, P. E. Native Chemical Ligation of Peptides and Proteins. *Chem. Asian J.* 2019, 14(11), 4611-4618. doi:10.1002/anie.201904411

Development of a bioreactor to mechanically stimulate cell self-assembled neotendons

Peter J. Wieber, Colin R. Marchus, and Nathan R. Schiele
Department of Chemical & Biological Engineering, University of Idaho, Moscow, ID



Abstract

Tendon injuries are common but current repair methods are inadequate. Even with surgical repair, scar tissue and incomplete tendon healing result in prolonged weakness which presents a risk for re-rupture. Thus, new regenerative treatment methods are required. To develop new treatments, mesenchymal stem cells (MSCs) have been explored in tissue engineering strategies to form tendon replacements. Our lab has developed a tissue engineering method to guide MSCs to form neotendons through directed cell self-assembly, which appear to mimic the early highly cellular stages of embryonic tendon formation. However, neotendon maturation in culture may be limited without the dynamic mechanical stimulation associated with *in vivo* muscle contraction. Applying mechanical stimulation is a unique challenge due to the neotendons' delicate nature and small size. To address this issue, a new bioreactor system was developed using SolidWorks modeling software. The bioreactor was designed to be watertight and incorporate a novel loading mechanism that secures and applies tensile loads to the neotendon, while remaining compatible with an existing motor and controller. Before resin 3D printing the bioreactor, resins were tested for cytotoxicity, and minimal changes in cell viability were observed. Using this new bioreactor design, neotendons were dynamically stretched (1% strain at 0.1 Hz for 4 hrs) and the cell morphology was qualitatively evaluated, compared to static controls. Outcomes of this study will advance tendon tissue engineering strategies by improving our understanding of how mechanical loading impacts tendon formation.

Background

- Tendons are essential for the transfer of forces from muscle to bone
- Current treatments are ineffective often due to scar formation
- Much of the current stem cell research works to mimic adult tissue structures
- Mimicking embryonic tissue may be more clinically relevant when it comes to tissue regeneration and repair
- Mechanical stimulation has been shown to induce tenogenesis in MSCs
- Scaffold-free 3D cell culture has provided difficulty to mechanically stimulate

Objective:
To develop a bioreactor system to mechanically stimulate 3D scaffold-free cell self-assembled neotendons and to assess how said stimulation affects cell morphology

Methods and Materials

Cytotoxicity Assay

- Resin samples were designed using SolidWorks 3D modeling software and were 3D-printed on a Stratasys J850 printer
- Potential volatile organic compounds and cytotoxic residues were extracted by incubating resin samples in cell culture media for 1, 2, and 3 days
- Cells were grown with resin extract media in a 12-well plate for 3 days
- Cytotoxicity was qualitatively assessed following ISO 10993-5:2009 Bioreactor Design Methods
- Components were designed using SolidWorks 3D modeling software
- Bioreactor was 3D-printed with Veroclear™ (VC) Resin on a Stratasys J850
- Accessory components were 3D-printed with PLA plastic on an Fused 3 printer

Mechanical Stimulation Methods

- Neotendons were grown at a seeding density of 3 million cells per construct
- After 48 hours of pre-culture, neotendons were loaded into bioreactor chamber
- Neotendons were cyclically loaded with 1% strain at 0.1 Hz for 4 hours

Design Criteria and Implementation

Soft requirements

- Accessories fit in a 50 mL centrifuge tube for easy storage and sterilization (1-5, 7, 9)
- Maintain alignment for future mechanical property test applications (1-3, 5-7)
- Minimize media usage (8, 9)
- Minimize cell trauma (1, 3, 5-7)
- Simplify loading procedure (1-9)
- Reduce undesired mobility (1-9)
- Reduce alterations to the existing neotendon architecture (3, 6, 7)
- Improve reproducibility (1-9)
- Easy to adapt modular design (1-5, 7-9)

Hard requirements

- Non-cytotoxic (1-9)
- Watertight (6)
- Compatible with existing motor and controller (1-9)
- Able to be disassembled (1-9)
- Secure neotendon without slipping or breaking (3, 4, 6-9)
- Allow for gas diffusion (6)

Figure 1: Real images and digital render of the bioreactor assembly. If a part meets a criteria, the part number is listed under said criteria. A) Top view, B) Front view, C) Exploded view under each label.

Proof of Concept

Dynamic Loading

Static Control

Figure 3: Representative fluorescent images of neotendons. A, C) Neotendon post mechanical stimulation. B, D) Static control neotendon. While cell nuclei are present, and actin is being produced, it is difficult to comment on cell morphology. Blue = DAPI stained cell nuclei. Green = Phalloidin stained actin cytoskeleton. Scale bar = 200 µm.

Discussion

- VC Resin was non-cytotoxic and did not leak
- Components successfully integrate with the motor and controller
- Ethanol sterilization led to bioreactor deterioration
- Bioreactor is capable of providing mechanical stimulation to the neotendons
- Loading and collecting process avoids breaking the neotendon
- Design is feasible for future mechanical studies

Conclusion and Outlook

- Resolve neotendon disintegration
 - Longer procedure
 - Treat with TGF-β2
- Address durability issues
 - Sterilize by autoclave, UV
 - Explore alternate materials
- Improve imaging process to reduce blurring and improve qualitative analysis
 - Remove neotendons from unexposed agarose
 - Spinning disk confocal microscope to address the 3D nature of the neotendons
- Western blot for quantification of protein

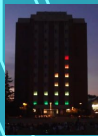
Figure 4: Characteristic problems seen over the course of the experiments. A) Breakdown of the neotendon after fixation in 10% formalin. B) Flaking on the periphery of the bioreactor.

Acknowledgements

The project described was supported by an Institutional Development Award (IDeA) from the National Institute of General Medical Sciences of the National Institutes of Health under Grant #P20GM103408, NSF Grant #2145904, and the Office of Undergraduate Research. The contents of the project are solely the responsibility of the authors and do not necessarily represent the official views of NIH.

WIRELESS TOWER OF LIGHTS

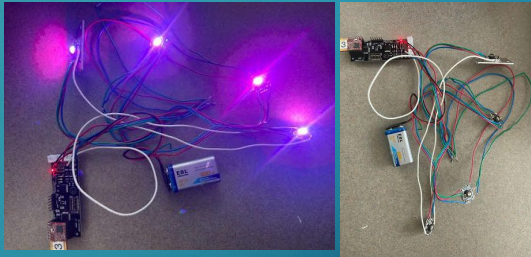
An undergraduate research presentation for the Idaho Conference of Undergraduate Research, conducted at 

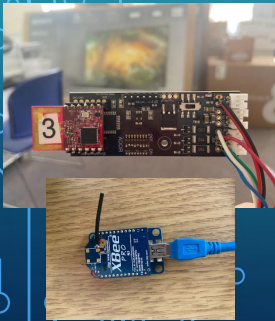


THE SITUATION

Every year, the University of Idaho hosts a lights show in the windows of the eleven-floor Theophilus Tower after the Homecoming serpentine march. Forty rooms are equipped with LED lights situated on wooden beams. All of these beams are connected into the wall through wire, which routes down with more wire to a networking closet in the basement, where more wire is connected to a large microcontroller, or the "brains" of the operation. *This is too much wire.*

The microcontroller communicates with all of the rooms to light up the LEDs, changing according to code written in C++, which is connected to a laptop via a lengthy wire out to the field where the music and lights display is broadcasted.





THE PROBLEM

This is a lot of wire to deal with. Not only does it make it difficult to set-up, all connections need to be ensured, and there is a small loss of energy through the wires to the top-level floors. To make the set-up for the Tower of Lights show easier, I collaborated with Dr. Rinker to create a wireless set-up for the Tower of Lights. To do this, we needed to think through two different problems: power utilization and wireless communication. Now that the power wasn't being drawn from a wired set-up, we needed to think how the LEDs could supply their own energy. For power, we re-designed our LED circuit to accommodate a common nine-volt battery. For communication, we utilized a wireless transmitter device that connects into the laptop and forty wireless transceivers attached to a small microcontroller, one for each room.

THE RESULTS

By switching to wireless technology using transceivers, we were able to address the communication challenges and overcome the issue of efficiency through wireless technology. We re-formatted the communication by placing hand-held microcontrollers on each beam and adding a transceiver to each. The mother of all transceivers that communicates to all is a transmitter that is connected via USB into a laptop using the Linux operating system. By re-designing the LED circuits, we were able to provide power to each LED beam and also add an extra LED to each beam. Setting two sets of two LEDs in parallel, or side-by-side, rather than in series, or a line-up, made the power running through the circuit more efficient without noticeably reducing luminous intensity.



University of Idaho

Reaped Electromagnetic Energy

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING,
UNIVERSITY OF IDAHO

Juwon Elelu



University of Idaho

Abstract

Radio Frequency (RF) can be said to be a collective term for electromagnetic energy. This form of energy is derived from electromagnetic radiation which travels through space between a transmission antenna and receiving antenna. The receiving antenna only captured a small amount of RF energy.

The purpose of this research is to design and build a system that can harvest ubiquitous unused RF energy and convert it to useful electricity. The device was composed of several units. First was the antenna responsible for collecting the Electromagnetic energy from the environment as AC current. In order for the device to power a load the current has to be in DC, and so an AC to DC converter or rectifier was used. This formed the second unit of the device. The last unit of the device, the microcontroller served as the load that was programmed to store a certain amount of energy in a capacitor by switch mode control. These units were designed individually, assembled as a circuit, then tested to get results.

Introduction

We are surrounded by lots of devices that use RF energy in our day-to-day activities. Such devices include mobile phones, remote controls, microwaves, Wi-Fi, radio transmission towers etc. Most of these devices make use of batteries as a source of energy or as backup energy. These batteries are changed from time to time. The used batteries are disposed of in such a way that they cause environmental pollution. So, the need for alternative sources of energy for powering these devices cannot be overemphasized.



Figure 1: Battery pollution <https://gsi.waste.com/battery-recycling-is-important-for-environmental-health/>

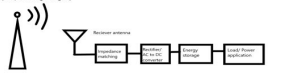
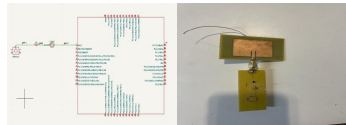


Figure 2: Electromagnetic energy harvesting system

Results

- Both Antenna and circuit board were designed and produced in hopes of collecting frequencies of 2.4GHz which is used in Wi-Fi.



Figures 3 & 4: Circuit board schematic and its physical form

- An oscilloscope was used to check the antenna and rectifier for signs of DC current being produced. Results show that they succeeded in performing their respective tasks. But in addition to this it was discovered that the diode also filters the output which was an unexpected behavior but useful. Useful in the sense that it could also act as a capacitor, allowing us to no longer need an actual capacitor and thereby saving resources



Figure 5: Result from reading of Antenna

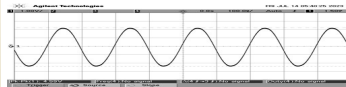
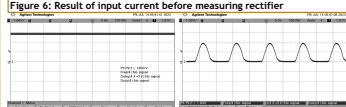


Figure 6: Result of input current before measuring rectifier



Figures 7 & 8: Result of output when measuring rectifier but with presence of filtration [6]; and result of output without presence of filtration

- The last unit, the microcontroller we picked, was an MSP430FR2476. According to the datasheet, this microcontroller was designed for a nominal power of 600uW which was acceptable for our purpose. It also had potential for switch mode control. Research was done to understand the microcontroller and how to control the pins, so a simple LED blink program was made as a start, serving as proof our original program is achievable.

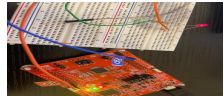


Figure 9: External LED blink program using MSP430FR2476 microcontroller

Conclusions and Future Directions

In summary of what has been accomplished so far, I designed and simulated my antenna with the aid of HFSS software to determine which material would be most suitable to make the antenna. From there I proceeded to search for a Schottky diode suitable to convert AC to DC, then I proceeded to making my pcb to allow me to test the parts for DC using an oscilloscope. Results showed that we were getting DC as an output which was a success, but this also led to the discovery that the diode could filter output, thereby acting as a capacitor. It was unexpected but it played in our favor and saved us resources. I used an oscilloscope to determine whether we were successfully getting DC from our circuitry and the outcome was a success. As for the microcontroller I was able to program it to control an external hardware which sets the basis for future work.

There are rooms for improvement for both the device and myself. I hope to finish the original program after better understanding the MSP430, from there I can combine all units of the device to make it whole and functional. From there I hope to include a sensor into the device to create room for more experiments. And as time goes future researchers can try new things as well.

References

- Aguilar, A., Davies, A., & Lorton, T. (2023, July 14th). Freely Reaped Electromagnetic Energy Mindworks. http://mindworks.github.io/wiki/Freely_Reaped_Electromagnetic_Energy.pdf, 2018-2017.
- Constantine, A. B. (2016). *Antenna Theory: Analysis and design* (4th edition). John Wiley and Sons, Inc.
- Hart, D. W. (1987). *Introduction to Power Electronics*. Prentice-Hall, Inc.
- Tran, L., Cha, H., Park, W. (2017). RF power harvesting: a review on designing methodologies and applications. *Micro and Nano System Letters*, 5(4), 1-14. <https://doi.org/10.1186/s40662-017-3051-0>

Acknowledgements

- Thank you Dr. Herbert Hess, Mr. Michael McMenamy, Philip Hagen, Dang Wamo, Aneesh Shrestha, Ella Vosburg, Department of Electrical and Computer Engineering, and SURF for your support till this point.
- This award was funded by an OUR Semester (or SURF) award 2023

Learn more about me and my research project at the following website: 



Tailocin treatment of American Foulbrood Disease in honeybees

Department of Biological Sciences | University of Idaho

Katherine Ryssel, James Van Leuven, Tracey Peters



University of Idaho

ABSTRACT

Tailocins are antibacterial proteins produced by some bacteria in order to kill closely related bacterial strains. In nature, this benefits the microbe by offering a way for them to control the bacterial composition of their environments. However, in a lab setting, researchers can use these tailocins to treat against unwanted bacteria. The purpose of this research project is to test whether a tailocin treatment is a viable option in protecting honeybees against the deadly American Foulbrood disease, which is caused by the bacterial species *Paenibacillus larvae*. To test this, the proposed research will involve three major parts: Collection and purification of tailocins from honeybee pathogens, in vitro analysis of tailocins against strains of *P. larvae*, and in vivo treatment of infected bees by tailocins. This work addresses the urgent need to develop novel antibacterials and reduce our dependence on traditional antibiotics. Currently, research remains in the in vitro stage of testing.

RESULTS

Five of 7 strains showed activity, but only 2 gave replicable results which resembled the inhibition of growth associated with tailocins. Strain B showed activity against four of the seven strains. One of the strains it did not show activity against was itself, which was expected as producing strains are resistant to their products. Strain D showed inhibitory activity against two strains, including one of the strains that B was ineffective against. D also showed prophage activity against strain C. Additionally, strains A and E both showed very light activity against B when lawns had very low bacterial concentrations. Strain G showed activity against 4 other strains in one test, but the results were never able to be replicated.

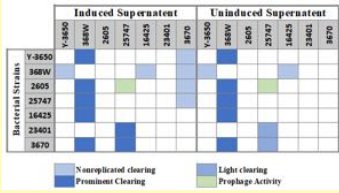


Figure 1. This matrix shows the results of spot testing supernatants against bacterial lawns. The left half of the figure represents induced samples, while the right half represents uninduced controls.

FUTURE WORK

- Activity from samples must be confirmed at tailocin activity by TEM imaging.
- DNA sequences will be obtained and used to locate gene clusters responsible for tailocin production.
- Gene clusters will be used to clone tailocin proteins and create samples of a higher concentration.
- In vivo experiments: Infection of honeybees with *P. larvae* and treatment with active tailocins.

The hope is that these tests will prove useful in the development of a possible commercial treatment of *P. larvae* infections in hives.

METHODS

- 7 strains of *P. larvae* were labeled A-E.
- Samples were grown into day cultures.
- Day cultures were subjected to stressful conditions to induce bacteriocin production.
- Samples were filtered to isolate the any tailocin-like particles
- Samples were spotted onto lawns of the original bacterial strains.
- Lawns were examined for inhibitory activity.

No Fire on the Mountain: Has fire suppression caused population declines of an imperiled ground squirrel?

A Test of the Fire Suppression Hypothesis

Ecology and Conservation Biology
University of Idaho | lvi8992@vandals.uidaho.edu

Alyssa Livingston
Courtney J. Conway
Eva Strand

Abstract

The Northern Idaho Ground Squirrel (*Urocyon brunneus*) is listed as threatened under the Endangered Species Act. The prevailing hypothesis for the species decline is encroachment of trees into its habitat due to fire suppression. However, this hypothesis has not been rigorously tested. Using geographic information systems and aerial imaging, I compared changes in abundance of the squirrels' populations to changes in forest canopy coverage over the past 40 years. These comparisons allowed me to test the prevailing hypothesis for the population declines of this rare species by testing the prediction that forest fire suppression has allowed tree growth and encroachment into the squirrel's habitat. This hypothesis predicts that the areas with the most pronounced population declines of Northern Idaho Ground Squirrels will have the most pronounced forest encroachment in the areas used by these squirrels. Our results indicate a 50% increase in tree cover over the colonies and the historical range for the last 40 years.

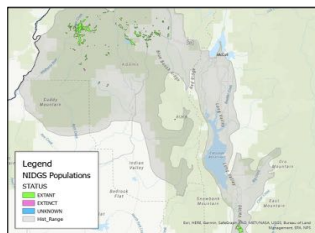


Figure 1: Map of Northern Idaho Ground Squirrel (NIDGS) colonies illustrating their status - extant, extinct, or unknown.

Project Description

The Northern Idaho Ground Squirrel (NIDGS) is a threatened species endemic to central Idaho. With already small numbers dropping, the species is threatened by extinction. The main hypothesis for population decline is habitat loss due to fire suppression, causing more trees to grow and encroach into natural clearings, which are the squirrel's habitat. This leads to a loss of suitable habitat for the squirrel and subsequent population decline. This hypothesis, however, has never been directly tested. The main objective for this project is to test the prevailing hypothesis for the squirrel's population declines.

Methods

- Programs utilized for this project: ArcGIS, Rangeland Analysis Platform, Google Earth Engine, and aerial photographs from the USDA over the past 40 years.
- Obtained ground squirrel count data from state and federal agencies to document variation among colonies in population declines.
- Documented change in tree cover over the past 40 years within Northern Idaho Ground Squirrel 1) historical range and 2) mapped colonies.
- Synthesized all these data to determine if the encroachment of trees is a likely cause of the squirrel's decline in abundance.

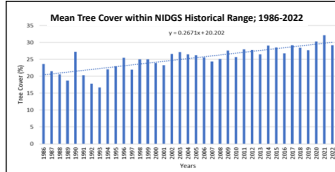


Figure 2: Change in the mean tree cover for the historical range of Northern Idaho Ground Squirrels (NIDGS) from 1986-2022.

Results

Two main analyses were run on ArcGIS Pro: zonal statistics of change in tree cover over the past 40 years within the historical range of the Northern Idaho Ground Squirrel and within the squirrels' colony areas only. Results of the first test show that there has been an increase in tree cover in the historical range over the past 40 years. The effect size shows a 50% increase in tree cover through the entirety of the historical range. Results of the second test show that there has also been an increase in tree cover in the squirrels' colonies over the past 40 years. The effect size again shows a 50% increase in tree cover within extinct and extant colonies.

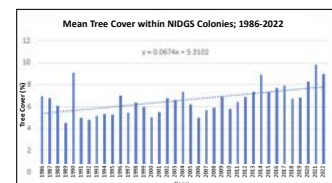


Figure 3: Change in the mean tree cover within colony footprints of Northern Idaho Ground Squirrels (NIDGS) from 1986-2022.

Conclusions

The fire suppression hypothesis - that squirrel population declines are caused by tree encroachment due to fire suppression - was supported based on 2 predictions. Forest canopy cover has significantly increased over the last 40 years in both the historical range of the Northern Idaho Ground Squirrel and also in the explicit colonies within their range. Canopy cover within the historical range (15% cover) was higher than canopy cover within the actual colonies (5% cover). Experts on this rare species believe that these squirrels need areas with <15% canopy cover.



Synthesis and Structural Characterization of Zinc Complexes with N,S Donor Ligands

DEPARTMENT OF CHEMISTRY, UNIVERSITY OF IDAHO

Mason Kilker, Alina Andrasi, and Sebastian Stoian



Abstract

Zinc (Zn) complexes are diamagnetic species with no unpaired electrons sought after for their unique chemical and biological applications as enzyme analogues or bioinspired catalysts; as such, Zn complexes are relevant to several different areas in pathophysiology and bio-inorganic chemistry.

The inorganic field of metal complexation has a diverse and important role in biological functions. For example, the binding of molecular oxygen (O_2) to hemoglobin involves forming coordinate bonds at alveoli of the lungs and breaking them in the tissues, while O_2 remains bound to the heme group during transport^[1]. The exact signaling mechanism has not been reported in literature^[2].

Alkaline phosphatases are hepatic enzymes distributed widely in mammalian cells^[3]. They are Zn-based complexes that are thought to have a role in cell signaling and catalyzing protein folding, though their chemistry and functions are not well understood. High mammalian alkaline phosphatase levels have been associated with liver and heart disease, with any physiologic role yet to be underlined^[2].

Given the Zn-regulated biological functions, it is important, of course, to acquire a fundamental understanding of model Zn-complexes and their properties in order to apply them further. The main goal of this short summer project was to prepare several novel series of Zn complexes and to elucidate their coordination modes, structures, and properties in solution and in solid state.

Introduction

The main goal of the project was to synthesize several Zn(II) complexes with a coordination number of 6. The complexes were to incorporate the tetradentate ligand 5,5'-bis(2-pyridylmethyl)-1,2-thioethane (**bpte**) with two anionic co-ligands NCX, where X=O, S; and BH₄.

Zn(II) used for these reactions was sourced from zinc perchlorate hexahydrate salt. Anionic co-ligands were obtained from their sodium or potassium salts, and **bpte** was synthesized using published methods^[4].

X-ray crystal diffraction at 100K was used to determine the composition of the complex in solid state, and ¹H-NMR was used to determine the composition in liquid state (DMSO-D₆ solvent). NMR was also used to verify the purity of **bpte**.

Several crystallization techniques were employed, including vapor diffusion and slow evaporation.

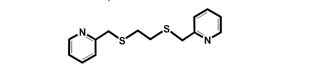


Figure 1: Structure of the **bpte** ligand

Results

Several novel Zn complexes were synthesized and characterized using x-ray crystallography and NMR. All compounds are hexa-coordinated and exhibit an octahedral geometry. The compounds were synthesized by allowing Zn perchlorate hexahydrate to react with **bpte** for 20 min., followed by the addition of a potassium or sodium salt of the anionic co-ligand.



This octahedral zinc complex was isolated as clear block crystals and exhibits a slightly distorted octahedral geometry around the metal center with an N-Zn-S angle of ~80°.

X-ray Crystallography

Single crystals were sent for x-ray diffraction. The result, as compared with the anticipated drawn structure, is shown below.

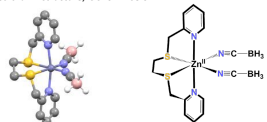


Figure 2: X-ray crystallography structure determination (left) and drawn structure (right) of [Zn(bpte)(NCBH₃)₂]. Hydrogen atoms other than those on the co-ligand were omitted for simplicity.

Nuclear Magnetic Resonance (NMR)

The NMR spectrum (below) was recorded for a sample obtained by dissolving single crystals in DMSO-D₆. The NMR indicates that the complex structure observed in solid state is maintained in solution.

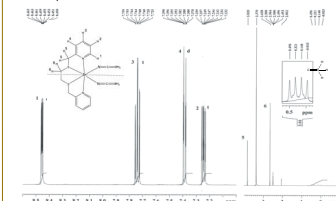


Figure 3: Nuclear magnetic resonance spectrum of [Zn(bpte)(NCBH₃)₂].

[Zn(bpte)(NCS)₂]

This octahedral Zn complex also exhibits a slightly distorted octahedral geometry around the metal center. Single crystals were sent for x-ray diffraction. The result, as compared with anticipated drawn structure, is shown below.

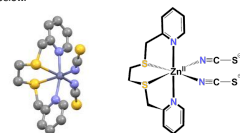


Figure 4: Comparison of the X-ray single crystal (left) and ChemDraw (right) structures of [Zn(bpte)(NCS)₂].

Conclusions and Outlook

1. A series of zinc complexes with a N,S donor ligand have been synthesized.
2. X-ray diffraction has been used to elucidate the solid-state structure.
3. Nuclear magnetic resonance has shown the structure to be rigid and maintained in solution.
4. Future work will explore other Zn complexes by attempting to make a dimer.
5. We will also explore other metals such as copper (II) and cobalt (II) for future structural analysis.
6. Further, we plan to study the interaction of these diamagnetic Zn complexes with biomolecules such as deoxyribose nucleic acid (DNA) or ribose nucleic acid (RNA).

References

- [1] Carbon Monoxide Poisoning: Pathogenesis, Management, and Future Directions of Therapy. Rose, J. J. et al. Am J Respir Crit Care Med, pg 596, 2017; Vol. 195.
- [2] Alkaline phosphatase: beyond the liver. Fernandez N. et al; Veterinary Clinical Pathology, 3rd edition (pg 223-227); 2007; Vol. 36.
- [3] 1,2-Bis[pyridin-2-ylmethyl]sulfany]ethane and its dimorphic hydro-chloride salt: Lennartson A. et al.; Acta Crystallographica Section C, 9th edition (pg m287-c372); 2011; Vol. 9

Acknowledgements

I would like to thank Drs. Stoian and Andrasi for their continued support in this project. Crystallographic data sets were obtained through the expertise of Dr. Craig Wheeler at Whitworth University using an instrument acquired using NSF-MRI grant (CHE-1827313).

This work was funded by an Office of Undergraduate Research SURF award.

Selective Reflections for the Nelder-Mead Algorithm

Zaiden Espe

Department of Mathematics, University of Idaho



Abstract

The Nelder-Mead Algorithm is an established algorithm to search for a minimum to a function. Since its first description, the algorithm has had various improvements made to it. With this project, I searched for improvements to the algorithm through changes to its reflective direction and geometric structure. I found in testing that directions that maintain the shape of the algorithm's search structure perform better than those that do not. The algorithm's speed can also be increased in higher test dimensions by increasing the number of points in the simplex by one. With these alterations, the Nelder-Mead algorithm can find solutions to problems it previously could not and do so with fewer function evaluations.

Methods

In a single iteration, the basic algorithm does not directly use all the information that is stored within the simplex. The algorithm overlooks the fullest extent of rank and value of the n-best points during an iteration. To use this information, I calculated new direction vectors to use as a basis for the reflection. To gather more information, I added an extra point to the simplex as a second point of reflection and used another mirror reflection to allow more movement of the simplex.

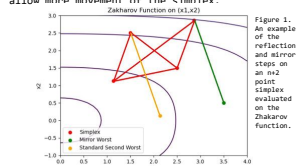


Figure 1: An example of the reflection and mirror steps on an n=2 point simplex evaluated on the Zakharov Function.

Introduction

The Nelder-Mead method optimizes a function of n variables by creating a simplex with n+1 points in an n-dimensional space. It then uses a combination of five steps to transform the simplex by moving the point with the worst evaluation to a hopefully better location. The direction in which it moves this point is what this project focused on studying. The standard algorithm moves the point in the direction of the center of the rest of the points, called the centroid. The centroid is calculated by taking the mean of the n-best points. Once the last ranked point has been moved, the algorithm starts again with the new set of points and iterates until a stopping condition is met. In a single iteration, the basic algorithm does not directly use a lot of information that is stored within the simplex.

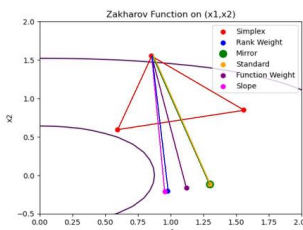


Figure 2: An example of each of the five tested reflections given a simplex evaluated on the Zakharov function.

Results

This project found that the additional point to the simplex improved the performance of the base algorithm without any changes to the reflective direction as the dimension of the function increased. The mirror transformation used with the extra point also helped the algorithm perform faster on multiple test functions and find more accurate minimums. However, more aggressive reflections that did not uphold the shape of the simplex as closely as the standard reflection or mirror reflection would often cause the algorithm to fail to find an acceptable minimum or perform within an acceptable speed.

Function	Size	n-min	n-val	n-min	n-val
Quadratic Sum	20	2.344075e-16	1489.2	6.877422e-17	2713.4
Quadratic Sum	100	5.713109e-16	18728.7	1.840766e-17	8161.1
Quadratic Sum	1000	6.847460e-16	21268.9	2.802710e-17	11097.4
Zakharov	20	2.709404e-15	18240.6	6.644022e-16	3161.2
Zakharov	100	4.207115e-15	16008.1	2.807309e-15	7805.4
Zakharov	1000	3.349320e-15	16008.3	6.780239e-15	12420.5
Ellipsoid-Price	20	6.600070e-01	4050.6	6.600070e-01	2597.9
Ellipsoid-Price	100	6.600070e-01	10401.2	6.600070e-01	10400.9
Ellipsoid-Price	1000	6.600070e-01	10000.2	6.600070e-01	10000.4
Booth-Beck	20	5.000000e-01	10000.1	5.000000e-01	10000.0
Booth-Beck	100	5.000000e-01	10000.1	5.000000e-01	10000.0
Booth-Beck	1000	5.000000e-01	10000.0	5.000000e-01	10000.0
Mc_Ellipsoid	20	1.844910e-15	1047.4	6.376230e-16	2779.9
Mc_Ellipsoid	100	5.749437e-15	11306.7	5.044012e-16	8778.2
Mc_Ellipsoid	1000	6.799506e-16	10407.1	1.378806e-15	11193.2

Figure 3: Data collected comparing the standard Nelder-Mead algorithm to the one found in this project. Note that "0.0" stands for dimension of the test function, "Mc_Ellipsoid" stands for the Rotated Hyper-Ellipsoid function.

Conclusions

These results open avenues to understanding the functioning of the Nelder-Mead algorithm and improving its design. Future research can be done to explore the effect of using even more points in the simplex, new transformations that continue to maintain the shape of the simplex and fine-tune the selection of multiple types of reflections in a single algorithm run.

References

- Nelder, J. A., & Mead, R. (1965). A simplex method for function minimization. *The Computer Journal*, 7(4), 308-313.
<https://doi.org/10.1093/comjnl/7.4.308>

Appendix 2

The Folk Influences on the Piano Works of Manuel M. Ponce

Alexandro Aguilar (aguui6621@vandals.uidaho.edu) and Dr. Roger McVey (rmcvey@uidaho.edu)

University of Idaho
Lionel Hampton School of Music

Motivation and Project Background

The compositions of musicians from underrepresented backgrounds have gone largely overlooked in the core literature for piano and in academic fields such as musicology and theoretical analysis. Inadvertently, the field of music has missed out on rich cultural inspiration by doing so. It is important to highlight music from people of color and help expand the scope of music as a studied form of art if the study of classical piano were to stay relevant in modern day.

For this project, I prepared four pieces for solo piano composed by Mexican composer, Manuel Maria Ponce, for performance. Research was done on the history of native folk music in Mexico and how it influenced Ponce's works for the piano.

The four works of focus throughout the project are Scherzino Mexicano, Romanza de Amor, Cuatro Danzas Mexicanas, and Intermexo No. 1. Latin folk genres of music and dance such as Huapangos, Sones, Cuban Contradanzas, Jarabes, and Corridos were discovered to have heavy influence in the rhythmic, melodic, sonic, and harmonic motifs found in Ponce's compositions for the piano.

Manuel M. Ponce (1882-1948)

- Born on December 5, 1882, in Tlaxiaco, Zacatecas
- Began studying the piano at age 6
- Made his first composition at age 9
- Attended the National Conservatory of Music in Mexico City in 1901 for one year
- Traveled to Europe in 1904 to study composition and piano in Italy and Germany
- Returned to Mexico City in 1908 and taught composition and music history at the National Conservatory
- In 1923, Ponce met Spanish guitarist, Andres Segovia, a lifelong friend who helped spread Ponce's influence as a composer around the world.
- Moved to Paris in 1925 for 7 years to work on his compositional technique.
- Moved back to Mexico in 1933 and spends the last 15 years of his life composing and teaching at the National Conservatory.
- Manuel Maria Ponce passed away in Mexico City on April 24, 1948

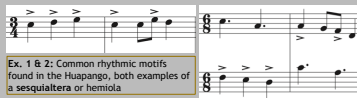


The Music of Mexico

The Mexican composer Carlos Chavez gives a definition to the term "Mexican Music" as "the native music of the ancient Mexicans, the music of Spanish or other origin implanted in Mexico, and the production in Mexico of a mixture of these elements."

Sons/Huapangos

- Mexican folk music and dance genre identifiable by the sesquialtera rhythmic motif and zapateado (tap dance) dancing
- Simultaneous 2 against 3 rhythmic motifs and alternating ternary and binary rhythms
- The **Huapango** is a regional sub-genre of the **Son**, known as the "Son Huasteco"
- The "Son Jaliscoense" originating in the region of Jalisco evolved into what we know as modern **Mariachi** music
- Call and response melodic motifs, originating from work songs sung by field workers, influenced the Son Jaliscoense, and later, mariachi music.



Corridos

- Mexican ballad genre identifiable by its narrative story telling
- Falsetto style vocals
- Melodies typically resolving in thirds
- Circle of fifths-based harmony
- Melodies voiced in thirds
- Chromaticism treated as ornamentation to melody.

The Piano Works of Manuel M. Ponce

Scherzino Mexicano (1909)

- "Dominant-Tonic" or circle of fifths based harmony, familiar to late 1800s to early 1900s Mexican **salon** music
- A melody voiced in intervals of thirds, akin to Mexico's early **Corridos**
- Familiar ABA form Ponce frequently used in his works for solo piano
- Huapango/Son** influenced alternating ternary and binary rhythms (sesquialtera)
- Mariachi-influenced call and response phrase structure



Ex. 3: Scherzino Mexicano - Measures 1-5

The Piano Works of Manuel M. Ponce (cont.)

Cuatro Danzas Mexicanas (1941)

- Synopcreted rhythms familiar to **corridos** in the A section
- Ambiguous chromatic harmony
- Two-part AAB form influenced by Cuban **Contradanzas**
- A as a faster introductory theme
- B as a slower and more contrastive theme
- Four and eight measure phrases
- Alternating groupings of duple and triple **Habanera**-based rhythms, familiar to the **sesquialtera**.



Ex. 4: Cuatro Danzas Mexicanas - Danza I - Measures 28-31

Conclusions and Future Directions

A lecture recital will be held at the Lionel Hampton School of Music where I will present my research on the traditional folk music of Mexico, a biographical overview of Manuel Maria Ponce, and I will perform the four pieces of music that were of focus throughout this project, **Intermexo No. 1**, **Cuatro Danzas Mexicanas**, **Scherzino Mexicano**, and **Romanza de Amor**.

I will also plan on applying to present my research at poster sessions hosted at music pedagogy conferences around the country such as the MTNA National Conference.

Scan this QR Code for a list of musical references pertaining to this project:



References

- Guerra, Dahlia Ann. "Manuel M. Ponce: A Study of His Solo Piano Works and His Relationship to Mexican Musical Nationalism." ProQuest Dissertations Publishing, 1997.
- Herrera Arizmendi, Omar. "Manuel M. Ponce: Style and Aesthetics." ProQuest Dissertations Publishing, 2012.
- Gaytan, Luis Francisco. "An Introduction to the Piano Music of Manuel M. Ponce." ProQuest Dissertations Publishing, 2014.

Acknowledgements

Thank you to Dr. Roger McVey for helping me prepare the pieces for performance and assisting me in my research

This award was funded by an OUR Semester (or SURF) award 2023

University
of Idaho

Anxiety and the Effectiveness of Misinformation Fact-Checks

DEPARTMENT OF POLITICS AND PHILOSOPHY, UNIVERSITY OF IDAHO

Kendall Mitton

University
of Idaho

Abstract

As levels of misinformation rise in the United States, so does the threat to efficient and effective policy-making. Most Americans are subject to misinformation, causing them to actively think/behave against the recommendations and empirical findings of experts. That said, in the absence of misinformation fact-checks and the presence of individual defiance toward corrective information, a variety of problems have been fostered within our borders (e.g., events like Pizzagate and conspiracies about Covid-19). Anxiety may be a factor contributing to this phenomenon, but it has been largely overlooked in previous research. Building off existing scholarship surrounding these variables, I conducted an online survey experiment to test the relationship between anxiety and fact-checks on individual perceptions. After analyzing my results, I found increased levels of anxiety and the presence of fact-checks do not have a significant effect on an individual's perception about the Covid-19 vaccine. However, anxiety itself has a negative and significant impact on an individual's perception about the effectiveness of the Covid-19 vaccine.

Overview

Background:

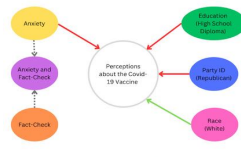
- What factors contribute to an individual's belief in misperceptions?
- Previous research shows...
 - Misinformation in the U.S. has created adverse complications for a range of different salient issues in politics, science, and medicine (Flynn et al., 2017).
 - In general, human emotions can have a significant impact on our actions and beliefs (Albertson & Gadarian, 2015).
- Hypothesis: I hypothesize an increase in the level of anxiety individuals have will lead to a decrease in the effectiveness of a misinformation fact-check.

Research Design:

- Nationally representative online survey experiment
- Original Survey Date: June 2023
- 607 respondents
- 2x2 between-subjects experiment
 - Independent Variables:
 - Anxiety Treatment (i.e., Artificial Intelligence article)
 - Anxiety Control (i.e., Virgin-Birth in Crocodile article)
 - Misinformation Treatment (i.e., Facebook post about the Covid-19 vaccine being harmful)
 - Misinformation Control (i.e., fact-check from PolitiFact about the Covid-19 vaccine being helpful)
 - Dependent Variables:
 - 5 opinion questions measured with a Likert scale

Results

- Interaction Analysis (Figure 1)
 - Anxiety Dummy: respondents induced with anxiety
 - Fact-Check Dummy: respondents presented with fact-check
 - Interaction: respondents from both groups above
- Figure 1 shows...
 - There is a negative but significant correlation between anxiety and individual perceptions. Substantively, a 1-point increase in a respondent's level of anxiety leads to a .35-point decrease in that respondent's average perception about the effectiveness of the Covid-19 vaccine.
 - Neither the presence of a fact-check nor the combination of both anxiety and a fact-check have a significant effect on an individual's perceptions about the Covid-19 vaccine.
 - A respondent only having a high school diploma, or being a republican, has a negative and significant impact on individual perceptions about the Covid-19 vaccine.
 - A respondent being white has a positive and significant impact on individual perceptions about the Covid-19 vaccine.



Conclusions and Future Directions

- Does the presence of anxiety and misinformation fact-checks influence an individual's perceptions?
- My research suggests no (kind of).
- This could likely be due to the topic (i.e., Covid-19 vaccines) I chose.
- In future research, one should explore the effects of other emotions that may lead an individual to hold misperceptions. Furthermore, one could examine other topics where common misperceptions are held.
- For example, what effect does trait aggression have on an individual's misperceptions. Or what factors cause people to hold misperceptions about election fraud in the US?

Acknowledgements

This research was funded by an OUR Semester (or SURF) award 2023

Figure 1

	Dependent variable:	
	Individual Perceptions	
Anxiety Dummy	-0.35***	(0.11)
Fact-Check Dummy	-0.09	(0.11)
Interaction	0.08	(0.15)
Age	0.004	(0.002)
Gender (Male)	0.09	(0.08)
Education (High School Diploma)	-0.40***	(0.10)
Party ID (Republican)	-1.08***	(0.10)
Race (White)	0.64***	(0.11)
Average Income (\$80,000 - \$84,999)	0.09	(0.29)
Region (West)	-0.06	(0.10)
Constant	3.04***	(0.16)
Observations	607	
R ²	0.25	
Adjusted R ²	0.24	
Residual Std. Error	0.93 (df = 596)	
F Statistic	19.77*** (df = 10; 596)	
Note:	*p < .10. **p < .05. ***p < .01.	

References

- Flynn, D. J., Nyhan, B., & Reifler, J. (2017). The nature and origins of misperceptions: Understanding false and unsupported beliefs about politics. *Political Psychology*, 38, 127-150.

Albertson, B., & Gadarian, S. K. (2015). *Anxious politics: Democratic citizenship in a threatening world*. Cambridge University Press.

Missing and Murdered Indigenous Women, Girls, and Two-Spirits in the United States

Amara Bailey (bail8404@vandals.uidaho.edu)
Dr. Omi Hodwitz (omi@uidaho.edu)
Department of Culture, Society, and Justice



Research Goal

The United States has a history littered with abuse against Indigenous populations. Today, there is an epidemic of Missing and Murdered Indigenous Women, Girls, and Two-Spirit individuals (MMIWG2). Despite Indigenous Women, Girls, and Two-Spirit individuals being at greater risk of victimization than other populations, their disappearances and murders are under-documented (Hodwitz & King, 2021). The MMIWG2 database aims to resolve the information deficit surrounding this phenomenon by being an exhaustive culmination of existing data from community-led efforts. Through the collection and subsequent authentication of each individual's case, the MMIWG2 database provides much-needed context to this epidemic for governing institutions in the United States to give this issue the time, attention, and resources it deserves. In addition to identifying the trends of this phenomenon, the MMIWG2 database provides an opportunity to analyze the response and effectiveness of law enforcement.

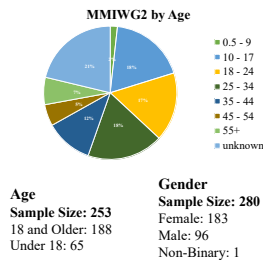
Research Questions

What is the demographic breakdown of MMIWG2s?
What is the demographic breakdown of their offenders?
Given the role of tribal police in law enforcement, how many incidents occur on reservation and require their involvement?
How many MMIWG2 cases are resolved?

Research Methods

Utilizing publicly available resources such as reliable news publications, existing public databases, government documents, and other community-led efforts, we are able to verify the authenticity of each MMIWG2 case. There are over 1,000 cases of MMIWG2s in the United States between 1980 and 2021 in the current data set. Roughly 30% have been identified as confirmed cases so far.

Victim Demographics



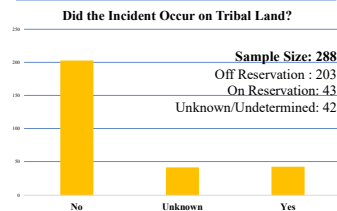
Offender Demographics

Out of 56 cases where there is at least one known offender

Age
18 and Older: 53
Under 18: 3

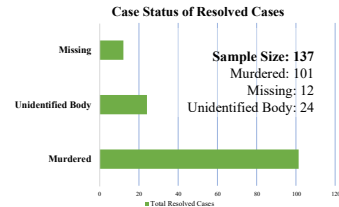
Gender
Male: 52
Female: 4

Incidents on Reservation



Case Resolution

Of the total confirmed cases, 244 have known outcomes. 56.1% of these are resolved, meaning an individual or their remains have been located. The remaining 43.9% of cases are still missing a body.



The data reveal a disturbing trend: the majority of MMIWG2 cases remain unsolved. Of the total confirmed cases, only 18% have both a known offender and a recovered body. Low resolution rates may indicate the ineffectiveness of law enforcement or a lack of accessible reporting systems for MMIWG2s.

References

King, S. and Hodwitz, O. (2020). What's the plan? Broadening the MMIWG2 conversation in North America, *Comparative American Studies An International Journal*, 17:3-4, Retrieved March 15, 2022, from <https://www.tandfonline.com/doi/full/10.1080/1477570.2021.1877082>

Funding

This research was funded by the University of Idaho's Office of Undergraduate research.

Final Report for HERC Funding for the 2023 Idaho Conference on Undergraduate Research (ICUR)

Submitted by Donna Llewellyn, Executive Director of the Boise State Institute for Inclusive and Transformative Scholarship

ICUR 2023 was held on July 19 and 20, 2023. Due to uncertainties related to COVID-19 and space constraints at Boise State, the conference was an online event with in-person receptions at each of the three research universities. We used the Fourwaves platform for the display of student posters and a synchronous poster fair and Zoom for synchronous talks and workshops. In terms of attendance, the participation was robust. We utilized the funding from HERC to allow each research university to reserve space and technology along with catering to host a local optional reception. In addition, we purchased a license to use a larger zoom room, and we needed a much greater amount of staff time to get the conference designed, planned, and implemented. We are grateful for the HERC funding that allowed us to hold ICUR this year.

There were 519 people who registered for the conference this year, with 335 participating in the Zoom sessions. This included people from over 30 different institutions/organizations. There were 196 poster presentations with a total of 533 project collaborators including 250 undergraduate students, 79 graduate students and 164 faculty (plus some postdoctoral fellows, high school students, and other community members). Our planning committee of representatives from the different colleges and universities across the state really worked hard to encourage and facilitate participation.

There were two days of workshops and presentations – see the following pages for the program schedule. More details are also available at <https://www.boisestate.edu/icur/>. Note that Boise State has disallowed the use of pdf programs due to accessibility issues so all materials for the conference were posted at the [event site](#).

A survey was been sent out to all of the attendees. The likert scale responses and an overview of the open-ended responses are attached. We intend to use these results to improve the conference next year, as we learn from our virtual conferences about what aspects of this event are best suited to a virtual setting and which parts really suffer from a lack of in-person interaction.

The funding from HERC went to the following categories of expenditures:

Item	Amount
Zoom license to allow for over 100 participants	675
Materials and Supplies	9
Receptions at BSU, ISU, UI	6072.57
Admin, Evaluation, and Director Support	33,324.43
TOTAL	\$39,991

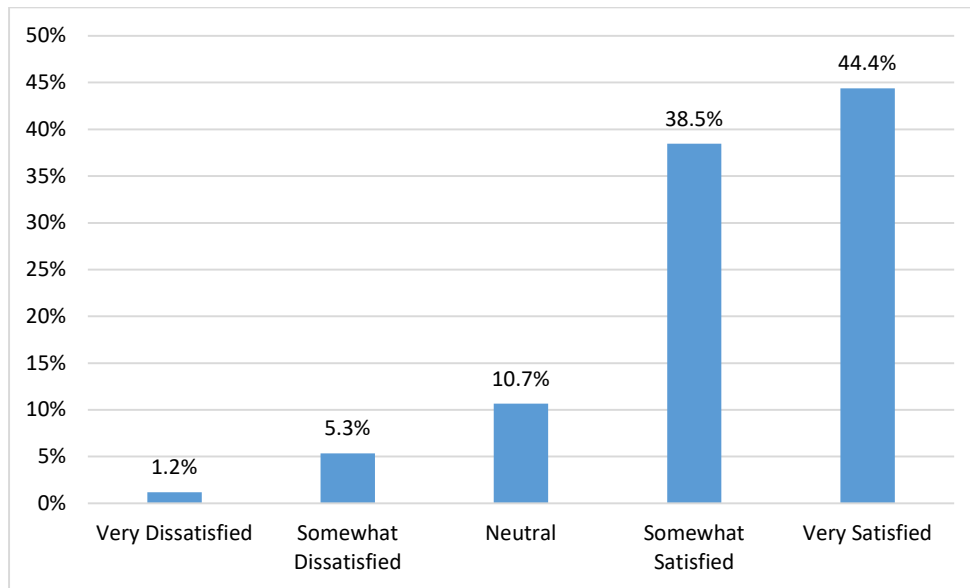
Day 1: July 19	
9:30 AM - 10:15 AM MDT	ICUR Opening Session
10:30 AM - 11:45 AM MDT	Lightning Talks
11:45 AM -12:45 PM MDT	Lunch Break
12:45 PM - 2:15 PM MDT	Networking: Meet a Prof
2:15 PM - 2:30 PM MDT	Open Discussion/Introduction to panel discussions
2:30 PM - 3.30 PM MDT	Faculty Panel: Flavors of UG Research
	Student Panel: Industry Opportunities
3:30 PM - 3:35 PM MDT	Transition back to main room
3:35 PM - 4:35 PM MDT	Panel
4:35 PM - 4:45 PM MDT	Closing
Day 2: July 20	
9:00 AM - 11:00 AM MDT	Paired Research Talks
11:00 AM - 11:15 PM MDT	Intro to Fourwaves
11:15 - 12:15	Poster Session 1
12:15 - 1:15	Lunch break
1:15 - 2:15	Poster Session 2
2:15 - 3:15 PM MDT	Poster Session 3
3:15 PM - 3:30 PM MDT	Break and transition back to Zoom
3:30 PM - 4:15 PM MDT	ICUR Closing Session

**Idaho Conference on Undergraduate Research 2023
Survey Results**

RESPONSE RATE: 35.3%

- 514 survey recipients (excludes 6 IFITS staff who did not receive the survey)
 - 329 (64.0%) students
 - 185 (36.0%) faculty/staff/other
- 172 recorded responses; 5 of these are incomplete responses
 - 3 of the incomplete responses answered no questions and are therefore EXCLUDED from analysis.

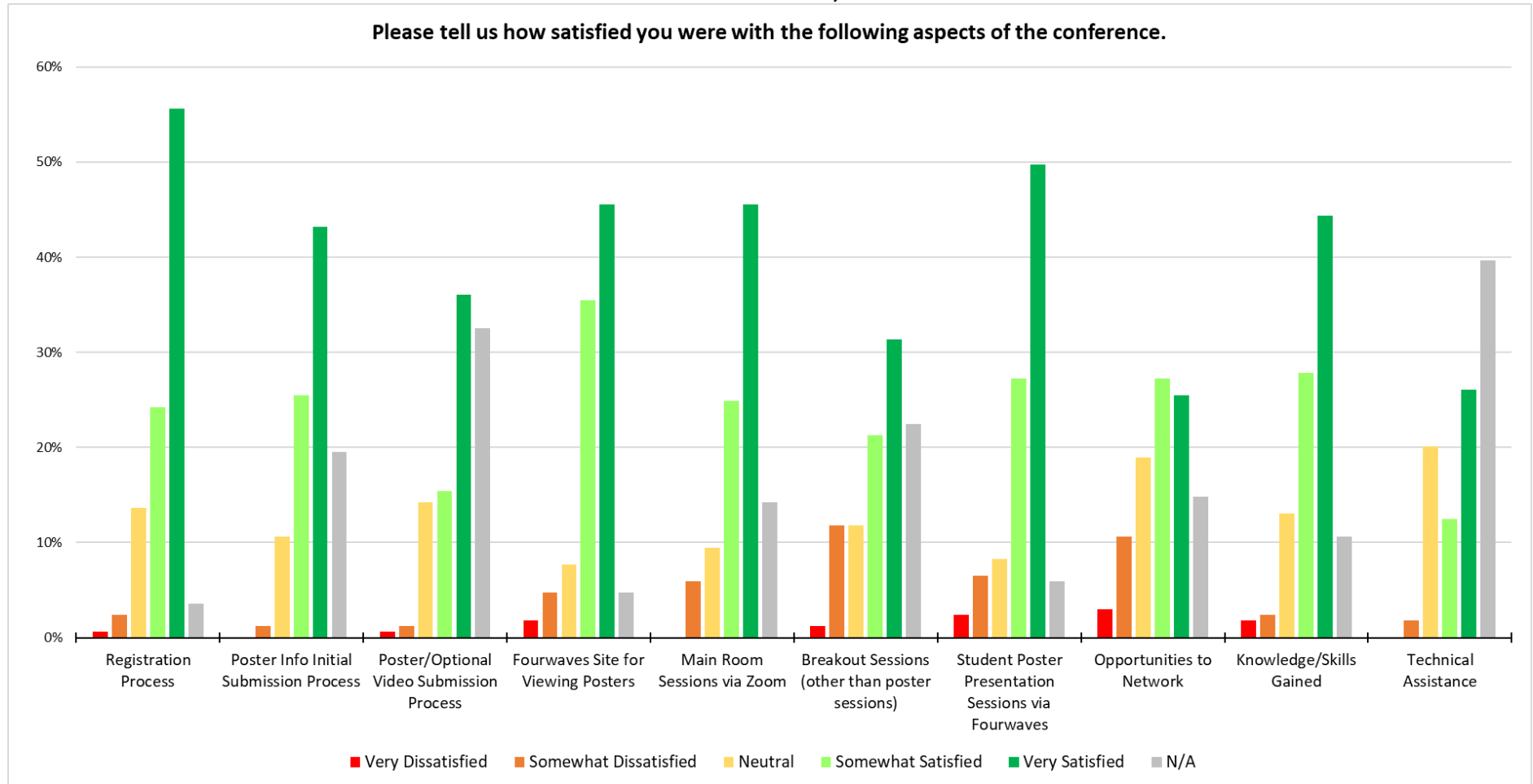
Please indicate your overall satisfaction with the 2023 Idaho Conference on Undergraduate Research.



Answer	%	Count
Very Dissatisfied	1.2%	2
Somewhat Dissatisfied	5.3%	9
Neutral	10.7%	18
Somewhat Satisfied	38.5%	65
Very Satisfied	44.4%	75
Total	100.0%	169

Please tell us how satisfied you were with the following aspects of the conference.

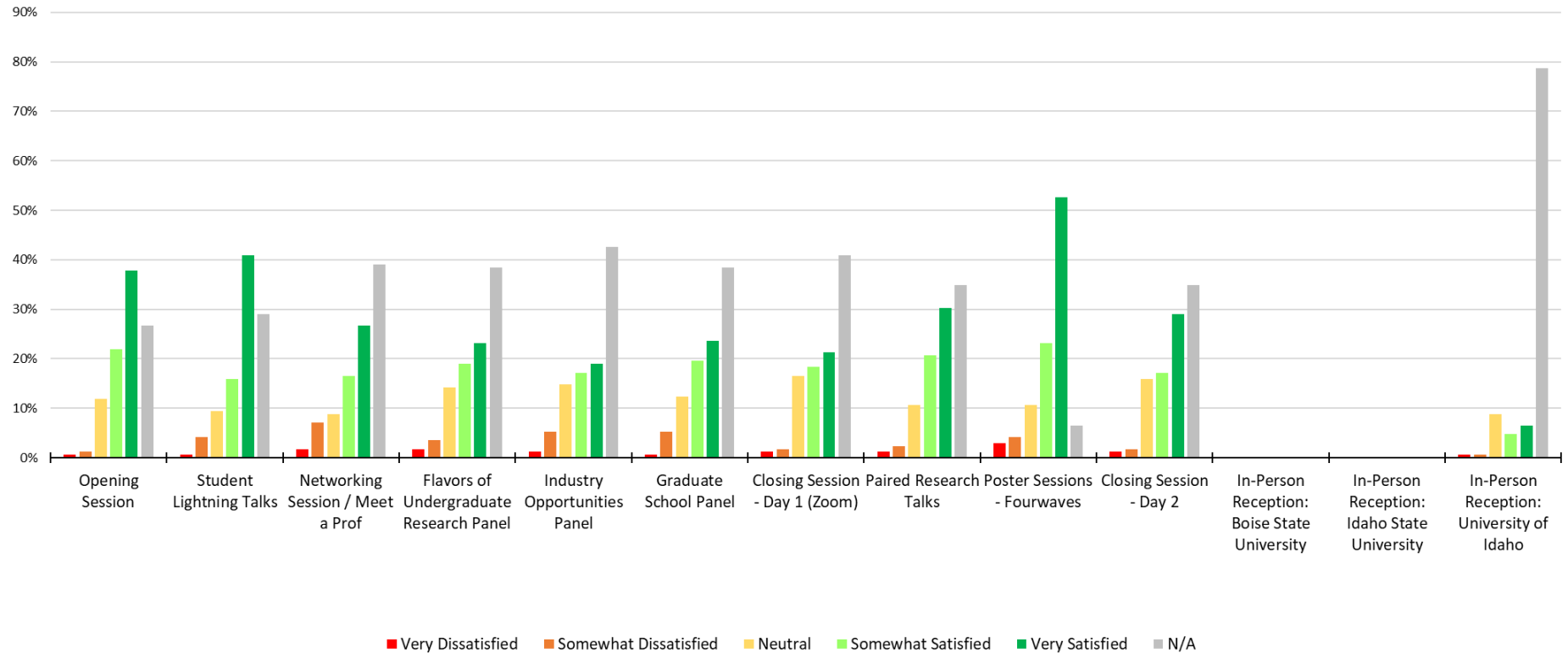
	Very Dissatisfied		Somewhat Dissatisfied		Neutral		Somewhat Satisfied		Very Satisfied		N/A		Total	
Aspect	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count
Registration Process	1%	1	2%	4	14%	23	24%	41	56%	94	4%	6	100%	169
Poster Info Initial Submission Process	0%	0	1%	2	11%	18	25%	43	43%	73	20%	33	100%	169
Poster/Optional Video Submission Process	1%	1	1%	2	14%	24	15%	26	36%	61	33%	55	100%	169
Fourwaves Site for Viewing Posters	2%	3	5%	8	8%	13	36%	60	46%	77	5%	8	100%	169
Main Room Sessions via Zoom	0%	0	6%	10	9%	16	25%	42	46%	77	14%	24	100%	169
Breakout Sessions (other than poster sessions)	1%	2	12%	20	12%	20	21%	36	31%	53	22%	38	100%	169
Student Poster Presentation Sessions via Fourwaves	2%	4	7%	11	8%	14	27%	46	50%	84	6%	10	100%	169
Opportunities to Network	3%	5	11%	18	19%	32	27%	46	25%	43	15%	25	100%	169
Knowledge/Skills Gained	2%	3	2%	4	13%	22	28%	47	44%	75	11%	18	100%	169
Technical Assistance	0%	0	2%	3	20%	34	12%	21	26%	44	40%	67	100%	169



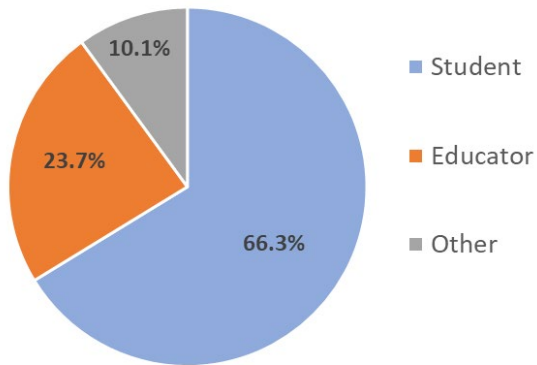
For each session that you attended, please let us know how satisfied you were with that session.

Session	Very Dissatisfied		Somewhat Dissatisfied		Neutral		Somewhat Satisfied		Very Satisfied		N/A		Total	
	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count
Opening Session	1%	1	1%	2	12%	20	22%	37	38%	64	27%	45	100%	169
Student Lightning Talks	1%	1	4%	7	9%	16	16%	27	41%	69	29%	49	100%	169
Networking Session / Meet a Prof	2%	3	7%	12	9%	15	17%	28	27%	45	39%	66	100%	169
Flavors of Undergraduate Research Panel	2%	3	4%	6	14%	24	19%	32	23%	39	38%	65	100%	169
Industry Opportunities Panel	1%	2	5%	9	15%	25	17%	29	19%	32	43%	72	100%	169
Graduate School Panel	1%	1	5%	9	12%	21	20%	33	24%	40	38%	65	100%	169
Closing Session - Day 1 (Zoom)	1%	2	2%	3	17%	28	18%	31	21%	36	41%	69	100%	169
Paired Research Talks	1%	2	2%	4	11%	18	21%	35	30%	51	35%	59	100%	169
Poster Sessions - Fourwaves	3%	5	4%	7	11%	18	23%	39	53%	89	7%	11	100%	169
Closing Session - Day 2	1%	2	2%	3	16%	27	17%	29	29%	49	35%	59	100%	169
In-Person Reception: Boise State University		1		2		20		11		49		86		169
In-Person Reception: Idaho State University		2		1		16		3		14		133		169
In-Person Reception: University of Idaho	1%	1	1%	1	9%	15	5%	8	7%	11	79%	133	100%	169

For each session that you attended, please let us know how satisfied you were with that session.



Please select your role.

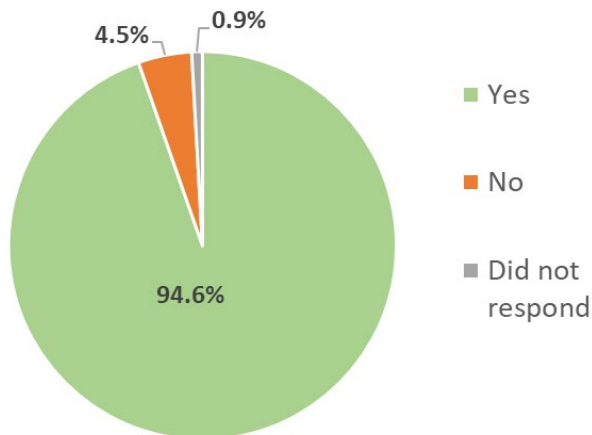


Answer	%	Count
Student	66.3%	112
Educator	23.7%	40
Other	10.1%	17
Total	100.0%	169

Other roles reported:

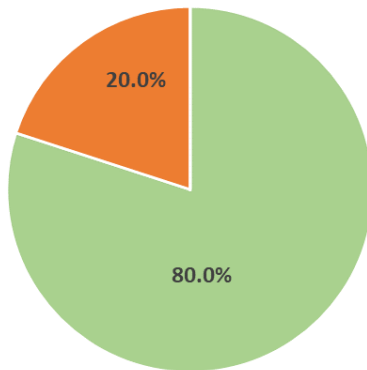
- Educator
- Industry
- Postdoc
- Staff
- Student

Did you present a poster? (This question presented only to the respondents who selected "Student" as their Role.)



Answer	%	Count
Yes	94.6%	106
No	4.5%	5
Did not respond	0.9%	1
Total	100.0%	112

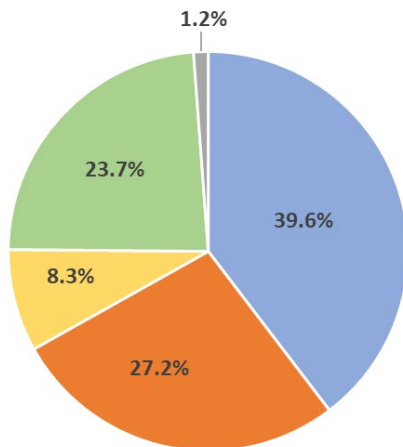
Were you a mentor of a student researcher who presented a poster? (This question presented only to the respondents who selected “Educator” as their Role.)



■ Yes
■ No
■ Did not respond

Answer	%	Count
Yes	80.0%	32
No	20.0%	8
Did not respond	0.0%	0
Total	100.0%	33

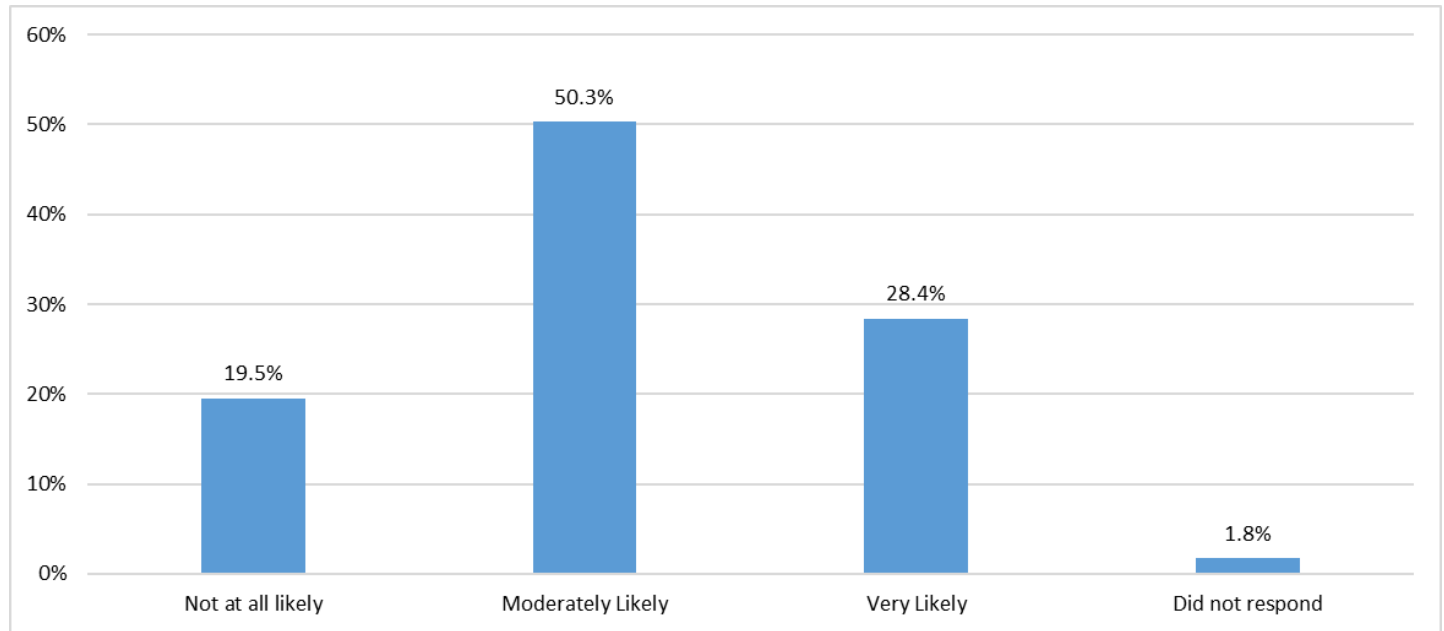
How many conferences (technical and professional conferences) have you attended including this one?



■ This was my first conference.
■ 2-3
■ 4-5
■ 6 or more
■ Did not respond

Answer	%	Count
This was my first conference.	39.6%	67
2-3	27.2%	46
4-5	8.3%	14
6 or more	23.7%	40
Did not respond	1.2%	2
Total	100.0%	169

How likely are you to attend ICUR next year?



Answer	%	Count
Not at all likely	19.5%	33
Moderately Likely	50.3%	85
Very Likely	28.4%	48
<i>Did not respond</i>	1.8%	3
Total	100.0%	169

How did you find out about ICUR?

The following table summarizes categories mentioned in the open-ended responses to this question and the count of respondents who mentioned them. The summary is sorted by the greatest number of mentions to the lowest. 140 respondents answered to this question.

CATEGORIES OF COMMENTS	COUNT
Specific faculty or staff member	29
SARE	16
REU program	12
Email	10
Student	7
Program requirement - not specified	6
Project SEED	5
I have previously attended	5
McNair	4
Fellowship	4
SURF	4

Internship	4
Student research participation (not specified)	4
Advisor	4
From the university/school (no specifics given)	3
IFITS	3
Not specified	3
ICUR committee	2
Lab - not specified	2
CAES	2
Office of Undergraduate Research (not necessarily BSU)	2
B2B	2
SRC	2
Announcements (not specified)	1
UI College of Science	1
Lewis-Clark State College Johnston's Lab	1
LSAMP	1
Website	1

What were your greatest lessons or take-aways from the conference?

The following table summarizes categories mentioned in the open-ended responses to this question and the count of respondents who mentioned them. The summary is sorted by the greatest number of mentions to the lowest. 134 respondents answered to this question; 19 mentioned more than one take-away. The sum of the category counts is 153.

CATEGORIES OF COMMENTS	COUNT
Learn about students'/others' research	32
Opportunity to present/practice presenting my research/poster	11
Exposure to research conference experience	9
Interacting with/meeting students	9
Networking opportunities	8
Learn to communicate to a large audience/people outside my field	7
Different paths to research/careers	6
Diversity of research	6
Graduate school info	5
How to present research/posters	5
In-person reception	5
Learn about fields and types of research	5
Interacting with/meeting faculty/professionals	4
Ability to support students	3
How to conduct research	3
Importance of mentoring	3

Perseverance in research	3
Value of research	3
Diversity of perspectives	2
Gained confidence to present/conduct research	2
Imposter syndrome talk/issues	2
Opportunity to present specifically in person	2
Paired research talks	2
Research is enjoyable	2
Research opportunities	2
Students' positive response to ICUR experience	2
Ability/potential/growth/empowerment of students	1
Attendance/participation level	1
Benefits of a remote/virtual conference platform	1
Breakout sessions - not specified	1
Criticism: Not in person	1
Feedback on my research	1
How to create a poster	1
Meet the Prof session	1
Okay to fail	1
Students' enthusiasm	1

Strong responses:

- STUDENT: *"After the 'talk to a Prof' session I really liked talking to one of the mentors. She was able to provide 'deeper' advice that many are not open to talking about. I resonated with the story she shared and hearing what she had to say afterwards were words that will forever be engraved into my brain. I appreciated her words and guidance so much, I reached out after ICUR to meet more often not just about research but the struggling of being a first generation student."*
- STUDENT: *"Student mentors care very much about the development of their students, and that investment in success makes a big difference."*
- STUDENT: *"I really enjoyed seeing how many other undergraduate students are interested by research. I also thought hearing from graduate students and students that had entered the workforce after completing their undergraduate degrees was useful. It demonstrated the variety of paths that can be taken."*
- EDUCATOR: *"WOW! Students are doing incredible work and I am hopeful for the future."*
- EDUCATOR: *"I love the camaraderie. It was inspiring to see the quality of the undergraduate researchers and how much they were benefiting from working with their faculty mentor."*
- EDUCATOR: *"It's great to have an accessible way for Idaho researchers to get together and showcase their work."*

The complete list of comments grouped by role follows, excluding “n/a” responses.

STUDENTS	
Student	A better understanding of the STEM research field
Student	A greater desire to continue with summer research.
Student	Actually getting the experience of presenting a research poster and sharing what research I actually conducted with peers and seniors.
Student	After the "talk to a Prof" session I really liked talking to one of the mentors. She was able to provide "deeper" advice that many are not open to talking about. I resonated with the story she shared and hearing what she had to say afterwards were words that will forever be engraved into my brain. I appreciated her words and guidance so much, I reached out after ICUR to meet more often not just about research but the struggling of being a first generation student.
Student	Being able to do the in person conference and talk to people
Student	Being able to present my research in a way that people from multiple disciplines could understand
Student	Being confident presenting my research.
Student	Experience
Student	Gaining experience doing poster presentations.
Student	Getting actually involved in presenting my research, and having to put it all together into a collective presentation.
Student	getting the opportunity to do research and share it with others
Student	Getting to connect with everyone
Student	Getting to see other posters on similar topics to my project. I was able to meet with some of the other researchers in my department and floor that I share, as well as researchers from other universities who worked on projects with similar goals to mine.
Student	Graduate students panel
Student	Hearing from the paired student-faculty researchers was really valuable.
Student	Hearing people from all over and what knowledge they offered
Student	How rewarding it is to be part of a research group
Student	How to communicate my research to a general audience; how to talk and listen
Student	How to present data to a broad audience
Student	How to present effectively
Student	I appreciated the knowledge gained with practicing presenting research in a variety of ways, and answering academic questions.
Student	I enjoy presenting.
Student	I finally felt confident in communicating my research to a variety of audiences.
Student	I got to connect with people who shared advise on how to better improve my project.
Student	I learned a lot about other people’s research and different projects going on.
Student	I learned that Imposter Syndrome is real and inevitable and that career path is limitless out there.
Student	I liked getting to know professors from all over Idaho.
Student	I love being able to network and see research outside of my field!
Student	I really appreciated hearing from the graduate students because it put a lot of things I was struggling with into perspective.
Student	I really enjoyed being able to see and talk to other students and professors from different parts of Idaho.
Student	I really enjoyed seeing how many other undergraduate students are interested by research. I also thought hearing from graduate students and students that had entered the workforce after completing their undergraduate degrees was useful. It demonstrated the variety of paths that can be taken.

Student	I really like in-person presenting.
Student	I really liked the grad school talks. I thought learning about experiences for everyone are different so really listening to myself and where I'm at in my career is what is most important.
Student	I think the most impactful part of attending the conference was talking to other researchers and getting to know new ideas.
Student	I was able to learn a lot about other research disciplines
Student	I was surprised at the range of projects taken on by participants.
Student	It was my first time presenting a poster and the most impactful part was the support I felt and the lack of judgement
Student	It was nice that I could practice poster presentation in a conference setting.
Student	It was really interesting to see what others were researching and how they went about it.
Student	It's okay to not know exactly what you are going to go into but still put forth the effort to learn.
Student	Learning about how the process
Student	Learning about new things and meeting others who were in similar situations as me.
Student	Learning about other areas of research and former students in grad school or industry.
Student	Learning about other students' projects and meeting professors from other institutions (I just wish we had more time for those things, especially the profs!)
Student	Learning about the different types of research conducted at Boise State
Student	Learning about the research of others
Student	Learning about the types and methods of research conducted in my field of study
Student	Learning how to communicate research and understand others research outside my own knowledge.
Student	Learning how to present complex scientific ideas to a general audience.
Student	Learning that everyone deals with imposter syndrome and doesn't actually know what they're doing.
Student	learning to present a poster for the first time
Student	listening to others' research is really fun
Student	Making and presenting a scientific poster
Student	Many people experienced failure
Student	My greatest takeaway was the opportunity to present a new poster I had not presented before. It helped me gain more presentation experience.
Student	My take away is that there is no need to rush.
Student	Networking with professors
Student	Other students were doing great work in other disciplines, some of which I didn't even know research could be done in.
Student	Others enjoyed my research and were excited to learn more
Student	Paired research talks were great!!!
Student	People outside of my discipline can still be interested in my research. Also, grad school isn't what I thought it was.
Student	Persistence is key.
Student	Poster presentations, learning about other research being done at my university
Student	Presenting my poster
Student	Presenting my poster and visiting others' posters.
Student	presenting research
Student	Research can be important
Student	Research extends to all fields and it is very exciting to hear other people talk about the work they are proud of
Student	Research takes more time then one might expect.

Student	Seeing friends from other disciplines come.
Student	Seeing research from other researchers in Idaho
Student	Seeing research goes beyond stem
Student	show up and try your best.
Student	Student mentors care very much about the development of their students, and that investment in success makes a big difference.
Student	Talking to other students about their research was the most impactful
Student	That all of our research is really interconnected as we're trying to better understand the world as a whole!
Student	That I don't need to have everything figured out right now.
Student	that I might be interested in public health
Student	That there's so many people passionate about so many things, and are trying hard to change the world.
Student	That undergraduate research is growing at Boise State, which is awesome!
Student	that undergraduate research is possible!
Student	The amount and variety of research that goes on
Student	The general process of making a research poster and then presenting it.
Student	The greatest take-away was how to present my research to others.
Student	the in-person presentation experience
Student	The in-person reception
Student	The intense research experience
Student	The most impactful part of attending ICUR was learning how to present my research.
Student	The posters
Student	The research skills that I learned along the way.
Student	The sense of community in the Research Industry.
Student	To continue to see what pathways everyone takes and what aspects of their lives I can apply to my own.
Student	To keep going down my path
Student	virtual conferencing is not the best format.
Student	What's it's like to present and experience.
EDUCATORS	
Educator	Diversity of research in Idaho
Educator	Great opportunity for students.
Educator	Great opportunity for students. Impressive knowledge.
Educator	great research opportunities
Educator	helping student develop their first-ever poster
Educator	helping students
Educator	How technology allowed me to connect with colleagues on different continents.
Educator	I just like seeing what the undergraduate students are doing and watching my own students grow in there awareness of the academic world
Educator	I love the camaraderie. It was inspiring to see the quality of the undergraduate researchers and how much they were benefiting from working with their faculty mentor.
Educator	I loved seeing so many student posters
Educator	In-person session - very valuable for students
Educator	Interacting with students
Educator	It was great to connect, even briefly, with other college instructors across Idaho
Educator	It's great to have an accessible way for Idaho researchers to get together and showcase their work.
Educator	Meeting excellent students and colleagues

Educator	Mentoring and time-management.
Educator	networking, and the introduction for many students to a professional scientific meeting
Educator	Our students are doing some excellent work!
Educator	seeing all of the variety in the ongoing research that in taking place in Idaho never fails to broaden my horizons
Educator	Seeing the quality of student work
Educator	Seeing the students in 2 projects with which I am associated describe their work to others.
Educator	student presentations for the interesting research, seminars for different models of undergraduate research-you did a great job with seminars and speakers
Educator	Student research presentations were very impressive
Educator	talking to folks at the live event
Educator	The level of attendance this year was fantastic.
Educator	The variety of high quality research projects involving undergraduate students.
Educator	Undergrads do great research.
Educator	We got a great couple of questions from one of our Boise State colleagues. It was very educational for the student, who had never done a poster presentation before.
Educator	WOW! Students are doing incredible work and I am hopeful for the future.
OTHER ROLES	
Other	Awareness of other work on campus
Other	Helped challenge me to ask insightful but balanced questions of the students.
Other	I was able to view posters of UI students.
Other	I was impressed with the work performed by the students and how well they presented their findings.
Other	It was a good opportunity for students to practice communicating their work
Other	It was great to see some of the posters in person at the reception and talk to each of the students!
Other	It was great to see the undergrads work on their projects. The timeline was too short, however.
Other	Listening to the excitement that the students had in their projects.
Other	no comment
Other	Student presentations
Other	The in-person session at ISU was amazing and we well put together.

What changes in the ICUR would significantly improve the conference experience for you?

The following table summarizes categories mentioned in the open-ended responses to this question and the count of respondents who mentioned them. The summary is sorted by the greatest number of mentions to the lowest. 102 respondents suggested at least one change; 15 made more than one suggestion. 70 respondents either did not answer this question or indicated they had no suggestions for improvement.

CATEGORIES OF COMMENTS	COUNT
Conference - general	53
Poster sessions	19
Other logistics	16
Plenary/breakout/other talk sessions	12
Networking	6

Reception	5
SRC	4
Discipline focus	2
No changes suggested	67

Highlights:

- Conference - general
 - 49 people desire resuming an in-person conference and/or did not like the virtual format*
 - 2 people suggested that ICUR be moved to later in the summer
- Poster sessions
 - 5 people said there were few or no attendees for a student's individual poster*
 - 5 people indicated a preference for in-person sessions specific to the poster presentations; these were generally geared toward allowing more time to see posters and/or having fewer posters available during a given session to increase audience size at individual posters OR grouping posters by discipline
 - 3 people made session structure redesign suggestions
 - 2 people had technological issues
- Plenary/breakout/other talk sessions
 - 5 people felt the sessions weren't long enough. There were specific mentions of the "Meet a Prof" session.
 - 3 people made session structure redesign suggestions*
- Networking
 - 4 people suggested better/more networking opportunities
- In-Person Receptions
 - 3 people felt the reception was too tight on space.
 - *This is likely specific to the Boise State reception, at least in the cases where posters were mentioned.*
- Other logistics
 - 5 people had technological issues
 - 4 suggested better/more communication of sessions and details before the conference*
- SRC
 - 4 people responded regarding SRC rather than ICUR and made suggestions regarding those sessions.

**Repeat highlight from last year*

Strong criticisms:

- STUDENT: *"This conference was heavily geared toward STEM majors. It made it very hard for outside majors to interact with everyone involved in the conference and have key takeaways."*
- STUDENT: *"Although it was eye opening to learn about other majors, I feel that I couldn't make a connection with non-STEM majors."*
- STUDENT: *"I would suggest having more in-person events to participate in. I know it is easier for people from all over the country to attend on zoom. However, I did not have a stable internet connection for a lot of the conference, and it was difficult for me to find somewhere else to connect to the internet that would have the quiet I needed. I know this is just a one time issue for me, but it would have been nice to have more in person events I could attend."*
- STUDENT: *"IN PERSON. I understand wanting to include a community of researchers from all over Idaho and that might be difficult to accomplish in person. However, the zoom meetings were not relevant or effective in the least bit. I would love to have better chances to network with other researchers. Zoom did not offer me that opportunity the same way that an in person meeting or casual dinner/reception would have provided."*
- EDUCATOR: *"The online part was nonsense and i did not attend the poster after not figuring our how it worked and seeing that poster were made for live sessions and not zoom session. the other part was that the icur posters were all too similar and dominated by certain PIs and topics. a single PI should only be on one poster to avoid this"*
- EDUCATOR: *"The conference needs to be in-person. The online format of presenting posters results in very few interactions, which prevents networking and prevents providing students the opportunity to really show off their research. Many students I polled after the conference felt it was a waste to invest so much time putting together a poster but only a few individuals visited their poster session. If ICUR is online again next year, then I will have students participate in another regional conference instead."*
- OTHER: *"The days were super long."*
- One student wrote an extremely long reponse; it may be found in the compiled comments list.

Changes/Comments by Category (sorted by the greatest number of mentions to the lowest):

CATEGORY > SPECIFICS	COUNT
<i>Conference - general</i>	53
Desires in-person / did not like virtual format	49
Change dates of conference	2
More undergrad focus	1
Too long	1
<i>Poster sessions</i>	19
Desires in-person / did not like virtual format	5
Few or no attendees for student's individual poster	5
Session structure redesign suggestion	3
Technological issue	2
Fewer students per session	1
Group by discipline	1

More diversity of content	1
More variety of fields	1
Other logistics	16
Technological issue	5
Better/more communication of sessions and details before conference begins	4
Change dates of conference	2
Group by discipline	1
Poster citations	1
Poster printing	1
Submission process is confusing/complicated	1
Website is confusing/difficult to navigate	1
Plenary/breakout/other talk sessions	12
Not long enough	5
Session structure redesign suggestion	3
Allow choosing which session/room/poster to attend	1
Better/more communication of sessions and details before conference begins	1
Desires in-person / did not like virtual format	1
Sessions were repetitive/had the same info	1
Networking	6
Better/more networking opportunities	4
Better/more communication of sessions and details before conference begins	1
Desires in-person / did not like virtual format	1
Reception	5
Too tight on space	3
Change dates of conference	1
Session structure redesign suggestion	1
SRC	4
Session structure redesign suggestion	4
Discipline focus	2
Make accessible to non-STEM majors	1
More science content	1
No changes suggested	67

The complete list of comments grouped by role follows, excluding “n/a” and “none” responses that do not elaborate further.

STUDENTS	
Student	Being able to network with each other more
Student	Being in person
Student	Being in person
Student	Being in person will be fun
Student	Being in person would be great

Student	Better access to information. Know what is going on in advance as to how we will be presenting and such.
Student	Can all ICUR in-person posters be printed for free ahead of time, so no students are dismissed, forgotten, regardless of where their home schools are?
Student	having in person events to talk to other researchers
Student	Having it in person would be much more engaging...
Student	Having it in person.
Student	Having the conference in person would be perfect.
Student	Holding the conference in person.
Student	Honestly, my only big issue with the conference was how confusing the website was. For example, when trying to find the zoom link, going to the ICUR website and clicking 'Schedule' would not show me the link, but if I went to my email and clicked the ICUR website link that was sent to me, it took me to a page labeled 'Schedule' which had the link. I still have no idea how I could have navigated to that page without the email. There were a few other situations like this where I had problems navigating the website.
Student	I believe it was ran very well and currently I do not have any suggestions on optimizing the ICUR experience.
Student	I believe the ICUR could be improved significantly by being an in person conference.
Student	I don't really think any that could be done by the organizers. There weren't a lot of posters or presenters from my field which lessened my enthusiasm a bit, but that's just how the draw goes with who presents.
Student	I feel like it would be interesting to have an in person conference but I understand the need for it to be online
Student	I have no major changes besides being in person, however, that's not applicable this year.
Student	I liked the in-person closing reception last summer (2022). It felt like the next best thing to having the conference in-person.
Student	I loved the idea of "meet a prof" but there definitely wasn't enough time to interact- too much time was taken introducing them.
Student	I think being in person will make ICUR much easier to talk to people and allow people to feel more open to visiting other people's posters.
Student	I think being in-person would greatly benefit the conference
Student	I think that being able to have to conference in-person would make the experience that much more interesting and poignant.
Student	I think that having more in-person events and sessions would be more impactful! That would involve a greater number of buildings or rooms, but I think it is a much greater way to make connections.
Student	I think that I would have benefited most if the session for "Effective Research posters" didn't just go through a "good" or "bad" looking poster but rather the actual process of constructing these posters. I would have liked getting more advice on how large a title should be. about how many words to use, how to edit and make pictures fit nicely, creating and choosing the right graph for the date we are using, or as simple as how do you set up a slide in PowerPoint or google slides to be edited. I found it that just going through multiple posters and finding similar patterns of what is ideal and what is not for a poster could have been narrowed down to only a few minutes and rather than extending that to a full hour session could have used that hour to go through tips and tricks on how to even make and edit these posters.
Student	I think the in-person presentations were much more enjoyable
Student	I thought having the in person closing ceremony before the actual conference started was a little strange. I also did not know about it until a few days before so I wasn't actually able to attend because I had prior commitments. Maybe next year it should be at the conclusion of the conference. Also, the conference being in person would be cool.

Student	I was not all that aware on how to network with other students and observers in the online conference. Some guidance on how to go about that would be much appreciated.
Student	I was satisfied with the ICUR experience
Student	I wish the breakout rooms were just a little longer so we had the opportunity to ask more questions.
Student	I wished that the students knew specifically that they are invited to attend all the sessions and not just the ones they were presenting.
Student	I would have preferred to attend the in-person ICUR, as the zoom conference was quite long.
Student	I would like to attend in person sometime.
Student	I would like to see it in person and I more flexibility with the guest speakers and choosing who I want to hear from.
Student	I would like to see more time spent actively helping participants create their posters and practice their presentations. I work as the only person on my project with little to no outside assistance from others in my lab. Therefore, I was unable to get outside feedback on my poster and presentation leading up to ICUR. I believed that the SRC meetings leading to the conference would help with that but I do not believe that they did. I found that the topics discussed in the beginning stages of SRC were the exact same topics discussed during ICUR prior to the Poster Sessions. Although there were different people talking about different experiences, the overall message and “guidance” given towards participants felt exactly the same. What I would have liked to see was more direct communication and hands-on guidance between SRC/ICUR participants and coordinators/advisors about the posters and presentations. I felt as though SRC established itself as a resource and guide for participants in preparation for ICUR but did not truly give useful guidance for how to create a poster and craft a presentation until it was too late. I personally felt as though I was expected to instead, lean on mentors and colleagues for preparation help, but that was something I did not have the luxury of receiving due to my project’s circumstances. I expected to have multiple SRC sessions leading up to ICUR that were purely focused on having students come with their posters and practice presentations to get feedback so they could adjust their poster accordingly. Instead, I got one session only four days before the Final Posters were due where I felt like I got the same experience as during the first SRC meeting. All we were able to do was explain what our project was about, but we didn’t get to adequately show our posters, practice a presentation, or gain feedback due to lack of time and the fact that some participants had not started their posters. I know of other participants within my own department who had mentors who actively set aside time for their students to practice and prepare for ICUR, something I, again, did not have. Therefore, I was placed in an unfair disadvantage in comparison because I was unable to prepare and make changes to a poster before the deadline. If SRC/ICUR had spent more meetings doing these kinds of exercises, I believe that this issue wouldn’t have existed. Lastly, I believe that ICUR itself occurred too early in the summer. While I understand that universities around Idaho begin and end their projects at different times, it was frustrating that ICUR occurred as early as it did. I do have a unique experience in that my research continues into the school year, but even then, the academic school year doesn’t start until mid-August. Therefore, there was about a month of time between ICUR and the start of the school year in which summer research could be, and is, still occurring. However, the information gathered in that time could not be presented. Participants who work on projects that last for different time periods are placed on a variety of schedules that can prevent meaningful work to be completed by conference time. Being on a more limited time scale reduces participants ability to work through and develop their research and turn it into a presentation. I talked with a handful of participants during early SRC meetings who were in similar situations to me in that they were unable to collect data or work on their project at all for weeks due to a variety of reasons. Therefore, all of us were placed at a disadvantage compared to other researchers who were able to join their project and start working immediately. Pushing back the date

for ICUR would allow for participants on a longer time scale to “catch up” to those who finished their projects earlier, therefore allowing for a more equalized level of research being conducted across all participants.

While I understand that ICUR is not about “gathering data” and that participants can present their project without gathering data at all, I still found it incredibly stressful to finally get data a week before the poster was due and then have only a few days to analyze that data and turn it into useable content for my poster. I felt as though I did not have enough time to adequately synthesize my data and create a poster that showed what I truly wanted to share.

If the “Poster Deadline” that was imposed this year was purely a “rough draft” deadline instead of the deadline for the final poster that could not be changed after submission, I do not believe that this process would have been as stressful and mentally taxing as it had been. Instead, I would have been able to show this rough draft to my peers and other advisors to gain helpful feedback on what could be improved upon in the poster as well as any additional information that they wanted to see.

In my opinion, this would be a significantly better use of time during SRC meetings leading to ICUR because it allows participants to not only gain a community of fellow undergraduate researchers, but it also actively helps them learn how to create posters and presentations, as well as how to take constructive criticism and use it to improve their project. This is something that everyone will experience at some point in their career, regardless of if they end up in a research field or not, and therefore it is vital to spend time practicing so that participants young and old, new or veterans to research, can understand how to take that feedback and use it to their advantage.

Overall, please consider pushing back the date of ICUR at least a week or two to allow for more time to be spent gathering data for projects that may have been setback for whatever reason. Further, please consider altering some of the original content of early SRC meetings and develop multiple meetings that instead focus on actively helping students craft posters and presentations and allow for feedback from peers. I believe that it is significantly more beneficial for participants to be given more time to learn how to craft presentations and gain feedback on them prior to ICUR. Finally, I believe that it is a much better use of time for some content from this year’s SRC meetings be kept primarily to the ICUR Sessions leading to the Poster Sessions to allow for more engagement during those presentations and free time to insert the suggestions I have made. All presenters at ICUR deserve to be listened to and focused on, however if participants have already learned what these speakers are advocating for, this does not occur. Instead, time should be spent preparing posters and presentations leading to ICUR so that participants can learn what they can do with the new skills and information that they have learned during the early sessions of ICUR.

I greatly appreciate that you have created this opportunity for undergraduate and even high school researchers to come together and I hope that this feedback will allow for this opportunity to improve even more in the future.

Student	I would rather it have been in person
Student	I would suggest having more in-person events to participate in. I know it is easier for people from all over the country to attend on zoom. However, I did not have a stable internet connection for a lot of the conference, and it was difficult for me to find somewhere else to connect to the internet that would have the quiet I needed. I know this is just a one time issue for me, but it would have been nice to have more in person events I could attend.
Student	If it were in-person, it'd be easier to be engaged and I would have hopefully had more than one person (who wasn't already familiar with my project) stop by my poster.
Student	If presenters were able to familiarize themselves with Fourwaves, as a presenter, before poster sessions.
Student	In person meeting, change the questions for the industry people to less about personal life and more about their role in industry, make more major specific

Student	In person poster presentation.
Student	In person!
Student	IN PERSON. I understand wanting to include a community of researchers from all over Idaho and that might be difficult to accomplish in person. However, the zoom meetings were not relevant or effective in the least bit. I would love to have better chances to network with other researchers. Zoom did not offer me that opportunity the same way that an in person meeting or casual dinner/reception would have provided.
Student	In-person would make networking and staying awake easier
Student	Just make it in person, as a whole.
Student	Make it in person
Student	make it in person
Student	More in depth talks with undergraduate students.
Student	More interactions between current grad students and the undergrad students
Student	More time in Meet the Prof breakout rooms to ask questions
Student	More time per session or fewer posters per session
Student	Moving away from the fourwaves platform.
Student	Not doing the conference online.
Student	not sure
Student	Nothing it was fine.
Student	Nothing, I liked how it worked.
Student	Nothing.
Student	Online meetings are really hard to stay excited about, in-person would be much more preferred and engaging.
Student	Perhaps transitioning better from smaller groups to bigger ones
Student	Providing more time in the breakout rooms for interaction with the professors would have been beneficial.
Student	Registration date being accurate.
Student	Scheduling SRC at a more convenient time
Student	Shorter weekly meetings!
Student	Splitting the posters up into more groups would help people view more posters
Student	Switching from Fourwaves to in-person or another format.
Student	Talks sometimes seemed to not align with what folks were studying. I was invited to the conference under the impression it was more biological science based but speakers or panel members were from political or communication backgrounds and that wasn't as helpful for me.
Student	The conference should be in person. Presenting a poster online was awful.
Student	The in-person conference could have been more structured to make the posters an important part of the event.
Student	The in-person reception in the Micron Center for Materials Research was super tight and hard to navigate, but pizza was an excellent idea.
Student	The poster session needs to be in person, i only had one person come to my poster so it felt like a huge waste of time and effort. Maybe do a poster award and have a group of judges so everyone could at least share their research with 2 judges
Student	The processing method
Student	This conference was heavily geared toward STEM majors. It made it very hard for outside majors to interact with everyone involved in the conference and have key takeaways.
Student	Would love the opportunity to do more in person poster sessions and networking!
EDUCATORS	
Educator	A slightly later date for the conference.

Educator	Attendance was very low. I am guilty of only attending the 2 posters of students in projects I am affiliated with, and not others. I think attendance online by non-presenters/mentors was very small. The process of nominating a student was ok for me, but unclear to others. It is summer and not everyone is around full time, so lead time needed to be more.
Educator	Can we please get a persistent link, DOI, and citation for the poster presentation? It is very convenient to be able to highlight the presentation for resumes and reporting purposes.
Educator	Having smaller poster sessions would increase the traffic flow so people would get questions. It was OK in person I think as people spread out, but I had a couple students that didn't get any visitors (besides me and the others in my group). Having more poster sessions (that are even smaller) would help.
Educator	having the conference in-person or using a different hosting platform. Finding and attending posters was challenging. If you attended a poster, you had to log out and log back in to attend another one in that same session. Having posters grouped (or at least searchable) by Discipline would be very helpful.
Educator	I know some students were disappointed at the lack of people coming to their poster session.
Educator	I like when the paired research talks were more conversational between students and faculty.
Educator	I think you do the best you could have using Fourwaves and having the conference on line. In person is a much more engaging event, of course. The main problem I had was that there were so many posters in each session and with the Fourwaves site, I could not visit very many, and some of my students did not have many visitors to their poster. In person, with people strolling to posters, this would be less of a problem. Thank you for the great event.
Educator	I though the conference was very well run. Personally, I would love to see it return to in-person simply for the increased interaction between attendees. I thought the BSU in-person reception was great.
Educator	It would be more engaging if the content was organized by topics/disciplines.
Educator	Larger room for the in person presentations. the room was too small for the number of presentations.
Educator	Maybe more in person at BSU. Next year I'll have my students give in person poster presentations but maybe not both in person and virtual. That is asking too much of them.
Educator	More in person poster presentations.
Educator	More in-person as feasible
Educator	More time for networking with both students and colleagues
Educator	please consider shifting back to an in-person conference: last year's student had zero visitors during the poster session and this year's only had one visitor outside our research group
Educator	Poster sessions should just not be done online.
Educator	The conference needs to be in-person. The online format of presenting posters results in very few interactions, which prevents networking and prevents providing students the opportunity to really show off their research. Many students I polled after the conference felt it was a waste to invest so much time putting together a poster but only a few individuals visited their poster session. If ICUR is online again next year, then I will have students participate in another regional conference instead.
Educator	The online part was nonsense and i did not attend the poster after not figuring out how it worked and seeing that poster were made for live sessions and not zoom session. the other part was that the icur posters were all too similar and dominated by certain PIs and topics. a single PI should only be on one poster to avoid this
Educator	Though no one at BSU realizes this fact, Idaho has two time zones. They have different times of day, separates by an hour. Therefore, whenever you post any scheduling at all, always include the time zone that is being used. It matters not how important or insignificant the event is, always include the time zone that is being used.
Educator	Trying to access the Fourwaves site the day before the conference to check out the detailed schedule, make sure I had access, etc. was frustrating since it wasn't really open yet. Might include some sort of statement with registration that says when the site will actually be accessible.

OTHER ROLES	
Other	Allowing students more time to work on their projects. I think posters should be divided into sessions based on topic to increase the number of people who engage each student. Really low engagement outside each students immediate work circle.
Other	For in person, larger space so posters are less crowded. Seems like that size crowd was not anticipated.
Other	Give the undergrads a little more time to work on their projects.
Other	I think that the all in-person finale planned for next year will be an awesome addition
Other	In person
Other	Some weird audio echoes on Fourwaves--not sure how to fix
Other	The days were super long.
Other	The login/sign up process was exhaustively tedious! Would have loved to be able to click a link and join/sign in with an existing account (i.e. Google single sign-on, etc)
Other	Virtual works, fills a niche, but I always prefer in person for the networking and learning that happens as well as the friendships that follow. You did nothing wrong, people worked hard. I just gave you my honest feedback.

2022/2023 Idaho ICorps Ignite After-Action Report

Program Overview

Idaho I-Corps Ignite was a pilot program that Boise State University (BSU), Center for Advanced Energy Studies (CAES), Idaho State University (ISU), and University of Idaho (UI) collaborated to deliver during the summer of 2022. The program was developed jointly by these Idaho institutions, starting with materials adapted by the BSU Venture College from a National Science Foundation (NSF) program named “Innovation Corps” (I-Corps).



This program has also been adapted by the National Institutes of Health (NIH) and the U.S. Department of Energy (DOE).



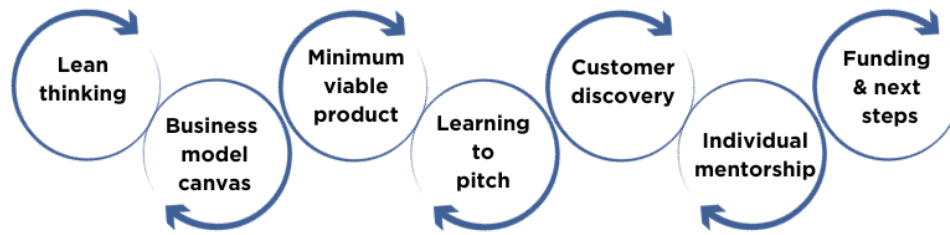
Designed to provide a cohort-driven learning environment, faculty and graduate students would receive training and resources to help move their research ideas closer to a real-world product or service, through a state-wide program meant to bolster connections between Idaho researchers.

The program was funded by in-kind contributions of faculty and staff time from each institution, and a \$2,500 stipend was provided for each participant.

The stipend was made possible by a \$40,000 IGEN HERC grant. The 6-week program began in June 2022 and met twice weekly for 90 minutes.

Informational fliers were circulated around each institution and the online application was made available on May 11, 2022, and closed on May 28, 2022, garnering 13 applications. Due to the generous funding, admission was extended to all applicants although not all applicants chose to participate. The cohort consisted of 7 teams, made up of five faculty members and one graduate student from ISU, one faculty from BSU, and one faculty from UI. The technology readiness level from the 2022 Ignite cohort varied greatly, with some participants having patented technology and some still in the ideation stage. The overall maturity of the technologies was notably young.

“ It was very fun, engaging, and informative. Being an entrepreneur is daunting so it was really nice to have experts holding my hand during the process. ”



The focus for participants was to learn the basics of how to test an academic research idea as the basis for a business. Participants learned how to better communicate about their research as a business idea, and how to incorporate feedback from potential customers into their product planning process. Each cohort meeting featured some time spent highlighting Idaho entrepreneurial resources for participants to leverage along the commercialization path, inside and outside the universities. All 7 participants completed the entire program, and during the last cohort meeting, each pitched their project to a virtual audience of university and community leaders.

Three \$2,500 follow-on funding opportunities were offered to each participant as an incentive to continue to develop their ideas. Participants would receive these stipends following the completion of milestones tailored to their technology and progress. Venture College staff met with each team to determine milestones to advance their ideas. All participants accepted this challenge to continue their entrepreneurial pursuits. Of these 7 teams, 2 completed their first milestone, receiving an additional \$2,500 stipend. One went on to complete a second milestone for an additional \$2,500.

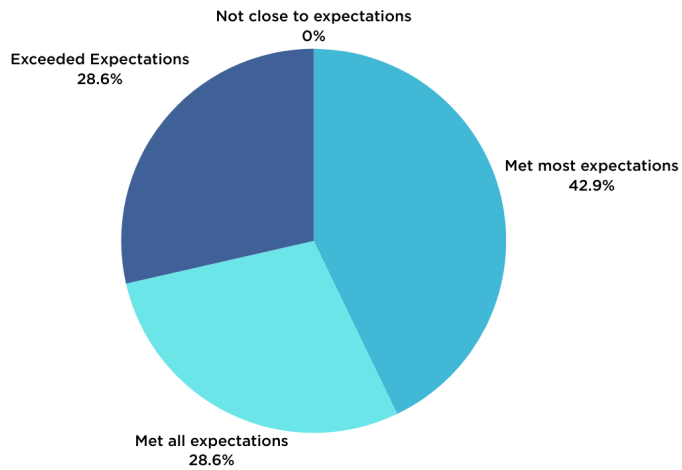
Following the completion of these milestones, remaining funding was used by each partner institution to provide additional incentives for faculty and student teams to participate in the NSF I-Corps Desert and Pacific Region Hub 4-week training. This program focuses on research-based technology venture products and services, allowing teams to realize the commercial potential of their research and innovation. Ten teams received a \$1,203.25 stipend for participating. Participants consisted of: 2 faculty from BSU, 1 undergraduate from BSU, 1 faculty from ISU, 1 faculty from UI, 3 undergraduates from UI, 1 researcher at Idaho National Laboratory (INL), and 1 undergraduate from College of Southern Idaho (CSI).



Participant Feedback Highlights

How did the class meet your initial expectations:

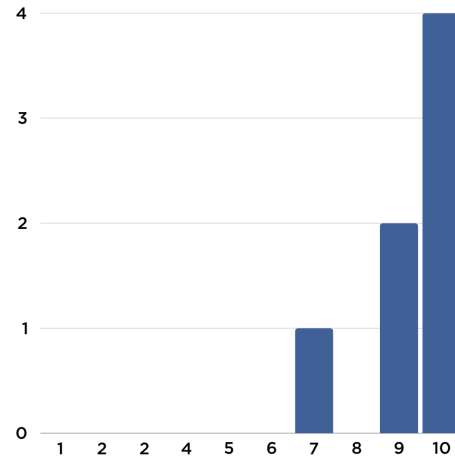
7 responses



How likely are you to refer Idaho Ignite to other faculty looking to launch their venture?

On a scale from 1 - 10 (1 not very likely, 10 very likely)

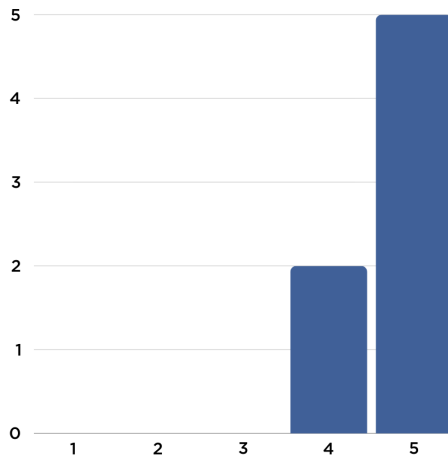
7 responses



After taking the course, how interested are you in commercializing your proposed venture?

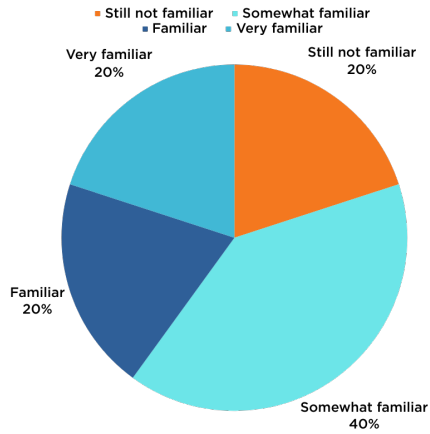
On a scale from 1 - 5 (1 not interested, 5 very interested)

7 responses



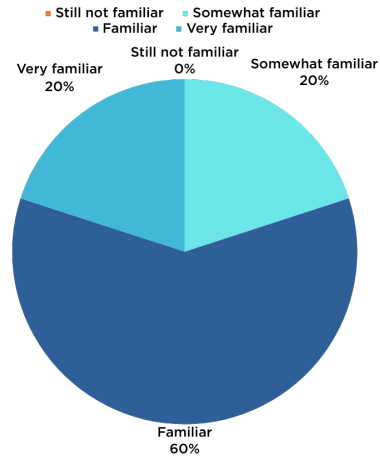
After the Idaho Ignite Program, how familiar are you with:

Research Council (HERC) Incubation Fund



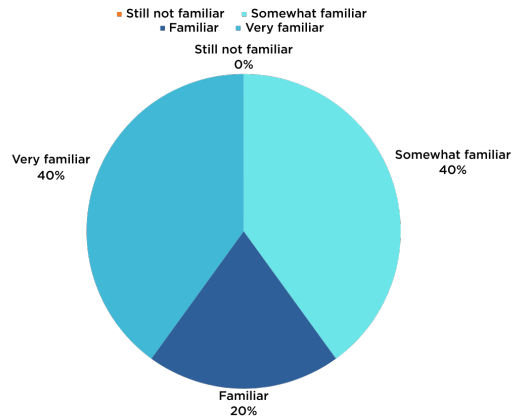
After the Idaho Ignite Program, how familiar are you with:

Idaho Global Entrepreneurial Mission (IGEM) Funds



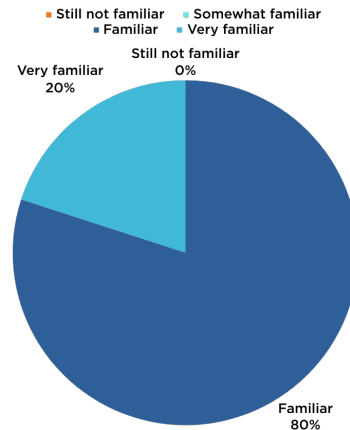
After the Idaho Ignite Program, how familiar are you with:

Small Business Technology Transfer

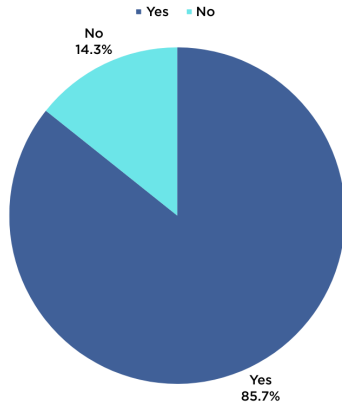


After the Idaho Ignite Program, how familiar are you with:

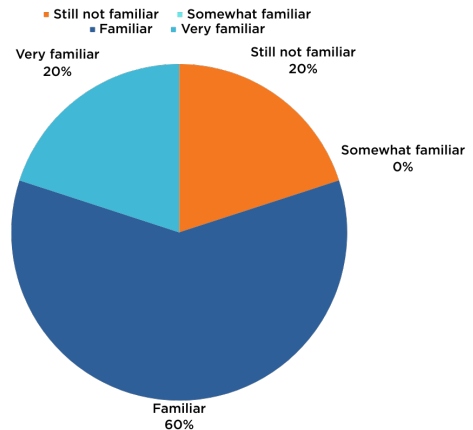
Small Business Innovation Research



After the Idaho Ignite Program, do you know how and where to submit an Invention Disclosure at your home institution?
 7 responses



After the Idaho Ignite Program, how familiar are you with:
 Angel/Venture Capital Funds



Program Budget Narrative

The budget for stipends for participating faculty ventures was \$40,000, broken down as follows:

Idaho ICorps Ignite Participant Stipends

- All 7 teams received a \$2,500 stipend for participating
- 2 teams met their second milestone
- 1 team met their third milestone
- Total stipends awarded: \$25,000¹

Milestones

	First	Second	Third	Total
1	\$2,500	\$2,500	\$2,500	\$7,500
2	\$2,500	\$2,500		\$5,000
3	\$2,500			\$2,500
4	\$2,500			\$2,500
5	\$2,500			\$2,500
6	\$2,500			\$2,500
7	\$2,500			\$2,500
Total Stipends Awarded	\$17,500	\$5,000	\$2,500	\$25,000

¹ Fringe benefits totaling \$2,850.91 are not included in the total stipend award amount.

NSF I-Corps Desert and Pacific Region Hub Participant Stipends

- 10 teams awarded \$1,203.25, for a total of \$12,032.50
- Remaining funds: \$116.59²

Staffing

The staffing was an in-kind contribution from each institution, with the primary program facilitation team consisting of the following dedicated professionals from each organization:

Boise State University:

- Ryan Vasso, Interim Director of Venture College
- Cara Van Sant, Interim Associate Director of Venture College
- Brett Adkins, Director of Technology Transfer

Idaho State University:

- Dan Cravens, Clinical Assistant Professor of Management, Bengal Solutions Director

University of Idaho:

- Jeremy Tamesen, Director of Technology Transfer

Teams	Stipends
1	\$1,203.25
2	\$1,203.25
3	\$1,203.25
4	\$1,203.25
5	\$1,203.25
6	\$1,203.25
7	\$1,203.25
8	\$1,203.25
9	\$1,203.25
10	\$1,203.25
Total Stipends Awarded	\$12,032.50

Lessons Learned

The bullet points below are recommendations from the participants as possible improvements moving forward:

- Highlight how to bring about a consultancy to spin off at a later time.
- Discuss ways to involve students and education in the entire process.
- Better help faculty navigate potential conflicts of interest for grant opportunities.
- A “next steps” class would be helpful, especially if mentors are included.

² The remaining \$116.59 will be returned to HERC.

- The creation of a resource center would be a good takeaway for participants to refer to throughout their entrepreneurial journey.

Next Steps

Boise State and University of Idaho are now recognized as members of the National Science Foundation's [Innovation Corps \(NSF I-Corps\) Desert and Pacific Region Hub](#), each receiving awards as part of a five year grant to fund entrepreneurial training for faculty, staff, and students at Idaho public universities and INL.

As an I-Corps member, these universities will collaborate with R1– or “very high research activity”– institutions to accelerate innovations that benefit the region and society.

NSF I-Corps Hubs provide experiential entrepreneurial training to academic researchers and graduate/postdocs across all fields of science and engineering, and help them translate fundamental research results to the marketplace. The I-Corps Hubs work collaboratively to build and sustain a diverse and inclusive innovation ecosystem throughout the U.S.

The Desert and Pacific Region Hub consists of the following universities: Arizona State University, University of Arizona, Northern Arizona University, UC San Diego, University of Hawaii, Boise State University, University of Idaho, and University of Nevada, Las Vegas.

Idaho ICorps Ignite will be paused for the foreseeable future as we focus our efforts on the NSF I-Corps programming. ISU, INL, CAES, and Idaho community college participants will have the opportunity to participate in these training sessions as they are partner institutions to both BSU and UI. This programming will take place over the course of 5 years, and this January we will kick off our 2nd year.

One consideration for Idaho ICorps Ignite is to serve a prerequisite to the NSF I-Corps regional training, however this will be determined at a future date once we have a better understanding of how it could lead into the NSF I-Corps training.

Other next steps include:

- Continue follow-on conversations with participants to track their progress, including but not limited to funding, services needed, patent applications, etc.
- Identify the types of barriers to faculty commercialization, including technical and financial barriers, as well faculty timelines and career policies, that impact the multi-year stages of the faculty commercialization process.
- Tailor efforts to the respective stages of the faculty commercialization process.
- Leverage existing federal commercialization programs, including NSF I-Corps, within the faculty commercialization process.

Appendix A
Summer 2022 Participants

- **Juliette Tinker | Pentamer Biologics, LLC**
Boise State University
Professor, Department of Biological Sciences & Biomolecular Graduate Program

Business Description:
Vaccine company targeting diseases in dairy cows.

Total Stipends Received: \$2,500

- **Mary Nies | Robotic Pets**
Idaho State University
Special Assistant to the Dean of the College of Health for Grant Writing, Tenured Professor

Business Description:
Robotic pets to decrease social isolation in assisted living residents.

Milestones Met: 1
Total Stipends Received: \$5,000

- **Melody Weaver | Gat a Friend in Me (GaFiM)**
Idaho State University
Assistant Clinical Professor, Graduate Studies

Business Description:
An interactive product to decrease loneliness in older homebound adults.

Total Stipends Received: \$2,500

- **Rifat Ara Tasnim | ARCoD**
Idaho State University
Ph.D. Student, Graduate Research Assistant, Department of Computer Science

Business Description:
A video game to measure the level of cognitive distortions through gameplay.

Total Stipends Received: \$2,500

- **Ryan Manwaring | Sperovue**

Idaho State University

Clinical Assistant Professor, Department of Clinical Psychopharmacology

Business Description:

Nonpharmacologic sleep aid for children, offering an alternative solution to conventional pharmaceutical interventions.

Milestones Met: 2

Total Stipends Received: \$7,500

- **Teresa Conner | (entity not yet formed)**

Idaho State University

Dean & Professor, College of Health

Business Description: A multi-component motorized device that allows a single therapist to safely gait train patients.

Total Stipends Received: \$2,500

- **Zachary Kayler | Idaho Soil Carbon Solutions (in process)**

University of Idaho

Assistant Professor, Department of Soil and Water Systems

Business Description: Hybrid education-consultancy entity offering services to producers interested in entering the carbon market.

Total Stipends Received: \$2,500

Appendix B
2022 NSF I-Corps Stipend Recipients

- **Arielle Levi | Relevarte LLC**

University of Idaho

Undergraduate Student

Business Description:

Fozzio Music Healing device that uses classical music and specific audio frequencies to provide consumers with a non-invasive healing solution.

- **Brandon Yagla | Sol Well**

College of Southern Idaho

Undergraduate Student

Business Description:

An all-in-one ground-based solar concentrator. Inspired by nature's brilliance, particularly the efficiency of the honeycomb structure found in beehives, the Sol Well harnesses solar energy in innovative ways.

- **Byung Kim | COIFM**

Boise State University

Professor, Physics Department

Business Description:

Novel scanning probe microscope called COIFM, enabling microscopy at the single molecule level as well as imaging biomolecular dynamics.

- **Cambria Brann | INE**

Boise State University

Undergraduate Student

Business Description:

Nail extension that is designed to both improve convenience and functionality in day to day life for those who choose to wear long nails.

- **Marcia Darling | StreamPad**

University of Idaho

Undergraduate Student

Business Description:

Device that provides an innovative way for livestreamers to interact with their stream and audience.

- **Ryan Manwaring | Sperovue**

Idaho State University

Clinical Assistant Professor, Department of Clinical Psychopharmacology

Business Description:

Nonpharmacologic sleep aid for children, offering an alternative solution to conventional pharmaceutical interventions.

- **Sarah Abraham | Caprine**

University of Idaho

Undergraduate Student

Business Description:

Luxury mohair knitwear brand.

- **Suketu Gandhi | X-Rad-i-CI Solutions**

Idaho National Laboratory

Chemist

Business Description:

Chlorine isotope separation research for molten salt reactors.

- **Tony Valayil Varghese | INFlex Labs**

Boise State University

Research Scientist, Material Science & Engineering Department

Business Description:

INFlex Labs provides nanomaterial inks that are compatible with multiple printer modalities, offering a solution of interchangeability between printers and an opportunity to choose between speed and precision for the customers.

- **Tyler Bland | Medimon**

University of Idaho

Clinical Assistant Professor, Idaho WWAMI Medical Program

Business Description:

Our technology, Medimon, is a cross-generational form of health promotion and disease prevention that utilizes a video game as a form of health science education.

IGEM Grant Report

☐ Progress (due Jan. 1) ☒ Annual (due Jul. 31) ☐ Final (due Aug. 31)

IGEM Grant # IGEM 22-001 Principal Investigator Edward Vasko

Submission Date July 31, 2023 Primary Institution Boise State University

The Cyberdome: An Investment in Idaho's Cybersecurity Future

Section 1: Summary of project accomplishments for the reporting period and plans for the upcoming reporting period.

Objective 1: Workforce development metrics:

For the reporting period, the Cyberdome project has funded an equivalent of 32 full student internships. During this period, student workers from 5 of our public institutions, including Boise State University, College of Western Idaho, College of Eastern Idaho, Lewis Clark State College, and University of Idaho worked together to monitor & detect client issues.

Objective 2: Risk reduction for clients:

For the reporting period, our technology platform reported a total of 78,809 client alerts to our student workers covering 4,783 total monitored assets in our client community. From these alerts, the students were able to analyze the reported data and filter this information to 6,449 possible incidents. These incidents were then further examined with our lead mentor team members for possible impact levels to our clients. Of the possible incidents, a total of 431 escalated to our clients. The team then worked with our clients to determine next steps and escalation paths. These alerts, incidents, and escalations would not have been caught without the technology, processes, and student workers in the Cyberdome.

Objective 3: Produce innovative research, tools, & techniques

Our Co-PIs and Graduate Assistants (GAs) submitted a total of five papers, with one paper being selected for publication. The papers range across topics such as: anomaly detection in process execution, malware polymorphism mitigation, cybersecurity predictive models, useful certificateless email encryption, and election security. After examination of the changes in cybersecurity workforce development frameworks, coupled with industry advancements, we made the decision to stop any further refinement of the one technology licensing/transfer involving predictive individualized training for cybersecurity workers.

Status of other planned accomplishments from last year's report:

Building recurring (annual) penetration testing offering for clients with vulnerability scans. After a successful test, our student team established test endpoints with two of our longest standing clients and are almost ready to begin initial tests on the actual scanning and

reporting process. While establishing the network pieces - which has been the most complex part – this student team has also been working on establishing reporting automation processes, which are already complete enough to test. If our initial tests prove to be both successful and the product useful to our clients, we expect to deploy the process to all our clients the second half of 2023.

Continue development of the Virtual City/CyberRange as a training platform.

In recent weeks our “Manticore” public range environment underwent significant retooling in order to create isolate computing sets for our Idaho sister schools & programs to utilize as part of the Idaho Cyber Range (project name: Chimera). This involved significant development effort for all the individual components necessary to implement significant networking and system isolation. All pieces have been initially tested & verified to work.

Continue activating Cybedome clients.

Increasingly complex clients provide real world experience for our engineers and analysts as they architect and implement sensors, and monitor the events and alerts, respectively. We have nine active clients and nine prospective clients in varying stages of movement forward towards activation, far exceeding our original grant goal of five clients. Two of these prospective partners include the Idaho Secretary of State and Idaho Rural Education Association.

Training improvements

The team continues to improve training for engineers and analysts based on new methods, approaches, and available content. This includes training on how to restore systems when they go down; how to build new system components from scratch; how to monitor the full security grid; and how to scan assets for vulnerabilities. Analyst specific training now includes exercises in simulated security events, how to detect and then threat hunt events, and how to manage cases (including client etiquette).

Platform refinement & automation

There are many regular, repetitive tasks involved in the regular upkeep of Cyberdome systems and lab environments, and student workers have been involved with documenting these processes. One such example is that automated reports being are pulled from Stellar via API and refinement of client deliverables is on-going.

Section 2: High-level summary of budget expenditures for the period just completed. If budget is underspent at time of report, explain why and plans for expending funds.

The table in Section 6 presents an expenditure report for the full-year of this period. An equivalent of thirty-two students, three graduate assistants, five faculty, and 2.5 full-time staff were directly supported by the grant in FY23. As in prior years, in FY23 we experienced a surplus in our Other Expenses (OE) due to much lower than anticipated Amazon Web Services (AWS) expenses. Our original grant proposal submitted in 2021 included an estimated \$62,700 towards subscription and storage costs while actual expenses were just under \$14,000. These surplus funds were used to pay for expenses including five months of effort from a full-time Engineering mentor and training materials to help interns work towards industry certifications.

Section 3: Demonstration of economic development/impact, including the following as applicable: patents, copyrights, plant variety protection certificates received or pending; technology licenses signed, start-up businesses created, and industry involvement; private sector engagement; jobs created; external funding; any other pertinent information.

Industry Involvement/Private Sector Engagement

A wide range of industry partners continue to express interest in supporting the Cyberdome's dual missions. Partners engaged in this period include: PlexTrac (www.plextrac.com), Sophos (www.sophos.com), AllPoints Logistics (www.allpointslc.com); Secure-IoT (www.secureiot.com), Hyprfyre (www.hyprfire.com) CRI Advantage (www.criadvantage.com), Silent Sector (www.silentsector.com), and Shadowscape (www.shadowscape.io).

Economic Development via Jobs Created:

Since the beginning of the reporting period, 31 student workers responded to surveys indicating their expected wage over the next year. Out of those 31 respondents seven indicated that they already had accepted a job offer and reported an average salary of \$51,666 per year. Those who had studied for either a bachelor's or master's degree reported a significantly higher salary of \$75,000 compared to those with an associate's degree that report an expected annual salary of \$42,000.

Additional funding received through leveraging the Cyberdome:

In the mid-year report, we identified an Idaho Workforce Development Council (WDC) Industry Sector Grant equal to \$800K over 3 years (approximately \$266,000/year). The grant period spans FY'23 through FY'25 with a possible extension into FY'26

Two other Federal grants leveraged the Cyberdome data/platforms for delivery/support. The first is a \$750,000 2-year grant from the NSA Center for Academic Excellence program. The grant is to develop AI/ML analysis graphs leveraging the Cyberdome datasets and platforms. The second grant is a \$280,000 2-year grant for a GenCyber instructor camp that will leverage the Cyberdome platform.

Technology Transfer/Licensing Opportunity:

After a detailed examination of the available solution landscape for individualized skill translation, combined with the recent update to the NICE workforce framework, it was decided to place any efforts for technology transfer on hold.

Section 4: Number of faculty and student participants as a result of funding, and brief description of student efforts.

Undergraduate students: For the reporting period, this project has funded an equivalent of 32 full student internships. Section 1 outlines various accomplishments of the team.

There are a total of three GAs and five Co-PIs working on the specific research areas of this grant. Specific Co-PI/GA accomplishments include submission of a total of five papers, with one paper being selected for publication. The papers range across topics

such as: anomaly detection in process execution, malware polymorphism mitigation, cybersecurity predictive models, useful certificateless email encryption, and election security. Paper development continues leveraging research on temporal graph neural network approaches to predict whether government organizations will be affected by a specific type of cyber-attack and a survey paper around the detection of fraud in elections.

Published papers, including:

- "Developing Accessible Email Encryption Using a Certificateless One-Way Key Agreement Scheme," 2023 4th Information Communication Technologies Conference, May 2023.

Section 5 : Updated details and/or progress on the long-term sustainability plan for the project and description of future plans for project continuation or expansion.

Federal, State, and private funding sources

Funding requests are being put forward in support of Governor Little's Cybersecurity Task Force objectives, of which PI Vasko was a member. The Cyberdome specific request included state appropriations equal to four (4) full-time support mentors, paid internships for up to 55 students across the state, and platform support for up to 18 rural communities. Barring changes from the President's Leadership Council (PLC) or other external factors, this effort is on-going with the new legislative session beginning in January, 2023.

Employer partners

PI Vasko is actively pursuing sustainable funding from employer partners for this program. Leveraging the identified "Activation Gap" thesis in our original proposal, employers are spending 6+ months activating new employees on methods and techniques. Under the thesis that the Cyberdome eliminates up to 3 months of that activation period, if an employer provides the Cyberdome between \$10,000 - \$15,000 as a gift, the employer potentially receives a tax-donation AND an employee that activates in their environment faster than ever before.

PI Vasko and our communication interns are executing on an outreach campaign to the Managed Security Service Providers (MSSPs) market across the nation, discussing the aforementioned sustainability model. PI Vasko is also speaking at regional and national conferences on the results of the Cyberdome enabling experiential learning for cybersecurity employers.

Section 6: Expenditure Report – Attach an expenditure report as a separate document showing expenses toward the original budget submitted for this project. The expenditure report does not count toward the page limit. A written summary of budget expenditures should be provided in section 2 of this report.

See attached expenditure report below. Explanation for line items that are under budget are provided in Section 2.

Expenditure Report

	Original Budget	Revised Budget	FY23 Spend*
Salaries	\$482,648.00	\$526,244.00	\$526,244.00
Benefits	\$107,974.00	\$100,100.00	\$100,100.00
Capital Expense	\$4,900.00	\$7,000.00	\$7,000.00
Other Expense**	\$115,478.00	\$77,656.00	\$77,656.00
Annual Totals	\$711,000.00	\$711,000.00	\$711,000.00

*Salaries and Benefits are projected numbers, but overspend is expected in both categories and will be handled via other funding sources with no impact to the HERC grant funds.

**The full-year budget takes into account a HERC approved carry-forward of \$11,000 from 2022.

IGEM Grant Report

IGEM Grant # IGEM 22-002 Principal Investigator Owen McDougal
Submission Date 06/15/2023 Primary Institution Boise State University

Boise State University Food and Dairy Innovation Center

Section 1: *Summary of project accomplishments for the reporting period and plans for the upcoming reporting period.*

From 07/22 - 06/23, our team has completed the design and planning of FDIC labs, obtained bids, and contracted with state approved contractors for laboratory construction of FDIC lab modules 1 and 2 to be completed in 2024. In year 2 of the FDIC HERC award, we proposed to submit 10 grants and generate \$1M in external funding. Now, at the end of FY23, we have submitted 22 proposals with 14 of them funded and three pending, for a total of \$3,130,366 (see Table 1). Our team also received BUILD Dairy funds in the amount of \$421,848 to support dairy research conducted by six graduate students and contribute to the hiring startup package for Dr. Konrad Meister (\$25K). The FDIC team mentored 12 graduate students, 45 undergraduate students, and 6 full-time staff. Of the estimated 3-5 publications/patents for FY23, our team has published four papers with more submissions in progress. Our goal of 5-10 internships and jobs for FY23, has led to five internships and three pending jobs at this time. Our plans for FY24 are to continue grant submissions, student mentorship, publication submissions, and promote internship and job opportunities for students.

Table 1. Summary of extramural funding activity in FY23.

External Funding / Grants & funding	YR1 Goal - 6	Funding Goal - \$500K	YR2 Goal - 10	Funding Goal - \$1M	YR3 Goal - 12	Funding Goal - \$1.5M
Grant Submission			22	\$24,927,028		
Grants Awarded	5	\$668,541	14	\$3,130,366		
Foundations/Gifts	0	\$ -	4	\$446,848		

Section 2: *High-level summary of budget expenditures for the period just completed. If the budget is underspent at time of report, explain why and plans for expending funds.*

The overall budget expenditures equate to 100%, however, some funds shifted category due to personnel changes, travel and equipment purchases that were posted to OE (<\$5K) or capital (>\$5K). The funds spent are in the following categories: infrastructure, instrumentation and equipment (104%); salary (82%) and fringe (56%); OE (241%); travel (147%); student tuition and fees (96%). The expenditures equal the total budget of \$684K.

Section 3: *Demonstration of economic development/impact, including: patents, copyrights, plant variety protection certificates received or pending; technology licenses signed, start-up businesses created, and industry involvement; private sector*

engagement; jobs created; external funding; any other pertinent information.

The FDIC has been exceedingly engaged with private sector companies as partners on external grants and as sponsors of funded projects. The companies and organizations that have contributed time, resources, and funds in FY23 include Agropur, Glanbia Nutritionals, Daisy Brand, Jones & Company Flavorings, Valley Food Tec, Dairy West, Lactalis, High Desert Milk, Cinder Wines, Telaya Winery, Split Rail Winery, Food Physics, Anheuser Busch, Global Gardens - Jannis Inc., Clextral, SREUS, Southern Fabrication Works, Giddy Group, Dairy West, and Chobani. These partnerships and collaborative grants have led to the hiring and continued employment of three postdoctoral researchers and two research technicians for the FDIC. Of the twenty-two grant proposals submitted in the past year, eleven of them included industry collaborators and described industry priority projects. Of twelve grants with industry partners, eight were funded, one is pending, and two were declined. Total external funding for the fourteen grants and BUILD Dairy contributions obtained during this reporting period amounts to \$3,577,241, with another \$259,183 pending. Industry partners have also provided internship opportunities for students in FY23. Table 2 gives an overview of our progress in securing internships and jobs for students since the FDIC was originally funded. The YR2 partners are DuBois Chemical (2 students), Lactalis (1 student), and Agropur (2 students). There are currently three FDIC students being considered for full-time employment with Food Physics Group.

Table 2. Summary of internships and jobs for students that have worked with the FDIC.

Internships/Jobs	YR1 (2-4)	YR2 (5-10)	YR3 (10-20)
Internships	6	5	
Jobs	2	3 pending	

Section 4: *Number of faculty and student participants as a result of funding, and brief description of student efforts.*

Table 3 provides a summary of student, staff and faculty participation in the FDIC. Students work together with FDIC faculty in independent research or through one of three Vertically Integrated Project (VIP) courses in (1) Food Systems, (2) Plasma Medicine and Agriculture, and (3) Let's Light up Science. The staff are postdoctoral researchers and technicians working with FDIC faculty. The faculty are FDIC team members and the expanded network of faculty collaborators for extramural grant activity or industry engagement through FDIC sponsored projects. In the past year, the team has hosted visits by Dr. Anand Rao, VP of Ingredients Innovation at Agropur, Dr. Eric Bastian, VP of Industry Relations at Dairy West and Director of the Western Dairy Center, Kristi Spence, Sr. VP of Marketing and Communication for Dairy West, Dr. Loren Ward, Chief R&D Officer at Glanbia Nutritionals, Neil Justesen, owner of Southern Fabrication Works (SFW), Kalen McKenzie, CEO of SFW, Don Thomason, VP Sales for Sustainable Renewable Energy Systems (SREUS), Paul Freeman, Co-owner of SREUS, Beau Lewis, Sr. Utilities Manager and Brett Hudson, Wastewater Supervisor for Chobani, Brian Meyer, Sr. Technical Director for Food Physics Group (FPG), and Brandon Nelson, Dir. Innov. Tech. Services, Fernando Munoz, Lab Ctrl. Mgr. and Ashraf Hassan, Mgr. R&D for Daisy Brand.

FDIC Student Training	YR1 (3-5)	YR2 (5-10)	YR3 (5-10)
Undergraduate Students	25	45	
Graduate Students	6	12	
Staff	6	6	
Faculty	5	16	

Table 4 provides a summary of students, academic degree programs, and a brief description of FDIC project activity. The student academic program has been provided to demonstrate the interdisciplinary nature of the work being addressed in the FDIC.

Table 4. Brief description of student effort associated with the FDIC.

Project/Topic	Student (graduate*)
PEF in potato chip processing	Mark Skinner* (MSMSE PhD), Alyssa Hendricks (CHEM BS), Tauras Rimkus (CHEM BS)
Dairy protein analysis	Rianat Lukman* (CHEM MS), Angelica Cabrera (CHEM BS), Joseph Collins* (BMOL PhD), Madison Dirks* (BMOL PhD), Elizabeth Ryan* (BMOL PhD), Habeeb Babatunde* (CS PhD)
PEF treatment of grapes for better wine	Matt Lorentz (CHEM BS), Kylie Johnson (CHEM BS), Alder Escobar (CHEM BS)
Bioactive ingredient degradation in ready-to-mix drinks and protein bars	Mia Rheede* (BMOL PhD), Nick Franklin (CHEM BS), Gennivyve Williams (CHEM BS), Morgan Fong (CHEM BS)
Bioactive alkaloids in kratom products; potato protein	Anna Shuey* (BMOL PhD), Delaney Odell (CHEM BS), McKenzie Riggs (CHEM BS), Jordan Hoover (CHEM BS)
Cold atmospheric-pressure plasma	Zahraa Alomar (BIOL BS), Kato Burgess (CHEM BS), Asher Chivvis (HealthSci BS), Zahraa Alomar (BIOL BS), Gracie Garringer (CHEM BS), Sarah Knowlton (CHEM BS), Taylor Koch (CHEM BS), Matthew Ostapovich (CHEM BS), Keaton Poe (CHEM BS), Christian Rainey (HealthSci BS), Stephanie Rood (BIOL BS), Konnor Sjullie (BIOL BS), Sevio Stanton (CHEM BS), Dalton Miller* (CHEM MS)
Biofilms in agriculture and biofilm experiments in medicine	Kyle McCleary (ECE BS), Cameron Waite (ECE BS), Madison Rizzo* (CHEM MS), Luca Manning (CHEM BS), Antonio Reyes (CHEM BS),
In-cell NMR analysis of metabolites	Cale Thorton* (CHEM MS), Wes Hirons (CHEM BS), Nicole Aughtry (CHEM BS),
Fluorescence detection of RNA	Steve Broyles* (CHEM MS), Aaron Stone (BIOL BS), Katie Matteo (BIOL BS), Jasmine Baclic (CHEM BS), Courtney Beard (CHEM BS)
Protein Characterization	Vyan Mohaamed (ChEM BS), Amber Hawley (CHEM BS), Hannah Herring (CHEM BS), Maddie Cardenas (BIOL BS), Chloe Day (BIOL BS), Kathryn Pierson (CHEM BS), McKenna Whiting (BIOL BS), Halle Torgerson (HEALTH STY BS), Kenzie Ballinger (CHEM BS), Gabe Miles (CHEM BS), Clariza Arteaga (BIOL BS)

Table 5 provides a summary of publications and patents associated with FDIC activity. In FY23, we proposed to publish 3-5 papers/patents and have four publications with more submissions in progress.

Table 5. Summary of publication and patent activity associated with the FDIC.

Patents & publications	YR1 (6)	YR2 (10)	YR3 (5-10)
Publications	6	4	
Patents	0	0	

Section 5: *Updated details and/or progress on the long-term sustainability plan for the project and description of future plans for project continuation or expansion.*

The long-term sustainability plan for the FDIC will be dependent on grant support and industry engagement. Our team will continue to submit proposals under the topics of NSF/USDA infrastructure (e.g., NSF Mid-scale Research Infrastructure-1, DOE EarthShot, NSF Convergence Accelerator Phase II, USDA NIFA Food and Nutrition Security, NSF RAISE, etc.), advanced manufacturing or center programs that build capabilities for support staff and academic programs to leverage sustainable operations that align with the CHIPS and Science Act. We will adopt (1) a recharge center model to include infrastructure for the industry to supplement financing for the center, (2) industry funds “facility use agreement” industry partners use the center equipment, and (3) industry directly funds research. In the final year of this IGEN HERC award, the PI will explore the initiation of a start-up company to facilitate the development of intellectual property for the promotion of economic development in Idaho.

Section 6: Expenditure Report – Attach an expenditure report as a separate document showing expenses toward the original budget submitted for this project. The expenditure report does not count toward the page limit. A written summary of budget expenditures should be provided in section 2 of this report.

Expenditure Report

Year 2 Budget Summary 6/30/2023									
	Year 2 Budget	BAR 4/6/2023	BAR 6/14/2023		Revised Budget	Total Expenses	Balance	Encumbrance	Available Balance
Salary	181,065.00	(10,685.78)	(22,199.65)		148,179.57	(148,179.57)	-		-
Fringe	69,006.00	(15,000.00)	(15,695.82)		38,310.18	(38,310.18)	-		-
Other Expense	32,843.00	25,000.00	21,378.15		79,221.15	(79,233.70)	(12.55)		(12.55)
Travel	3,900.00	1,123.78	714.72		5,738.50	(5,738.50)	-		-
Student	10,626.00	(438.00)			10,188.00	(10,188.00)	-		-
Capital	386,560.00		15,802.60		402,362.60	(402,362.60)	-		-
Subtotal	684,000.00	0.00	-	-	684,000.00	(684,012.55)	(12.55)	-	(12.55)
Indirect 0.0%	-				-	-	-	-	-
Total Costs	684,000.00	0.00	-	-	684,000.00	(684,012.55)	(12.55)	-	(12.55)
									100%

The BAR 6/14/2023 column which is highlighted in yellow, represents expenses that have yet to be approved by IGEM HERC at the time of submission of this annual report.

IGEM Grant Report

☐ Progress (due Jan. 1)

☒ Annual (due Jul. 31)

☐ (due Aug. 31)

IGEM Grant #23-001

Principal Investigator – Prof. Michael Haney

Submission Date – 2023.07.31

Primary Institution – University of Idaho

Library of Reconfigurable Immersive Attack and Defend Scenarios for Cybersecurity Research and Workforce Development

Section 1: Summary of project accomplishments for the reporting period and plans for the upcoming reporting period.

- Built a new Reconfigurable Attack-Defend Instructional Computing Laboratory (RADICL) at the University Place campus in Idaho Falls. This novel, immersive environment is integrating physical processes, full-scale enterprise IT systems, and Internet-scale cyber-attacks on-demand to offer researchers, students, and trainees a controlled live-fire environment like no other currently available. The laboratory will be a hybrid virtual and physical environment allowing access from across the state through the Idaho Cyber Range.
- Development began of the laboratory focused on power system communication and control systems. We have expanded our relationships with industry partners, including Schweitzer Engineering Laboratories, Westinghouse (now WESCO), Datacast Technologies, and Edge Velocity to begin integrating their technologies into the laboratory. This includes significant donations from the vendors to complement Idaho's investments through the HERC IGEN program. We have also used matching funds provided by the university to procure the real-time digital grid simulator and have begun initializing it.
- Produced four journal publications, five conference papers, and used our expertise to deliver a report to the U.S. House of Representatives regarding the cybersecurity of the electric distribution system, to be made public in the coming months. We have also submitted five additional funding proposals based on the preliminary research performed in the laboratory, including to DOE Cybersecurity, Energy Security and Emergency Response (CESER) for nearly \$3mil. We have also been successful in securing an additional \$100,000 per year from our partnership with the INL for our work in the lab focused on grid data transport and security.
- Introduced a framework for effectively and quickly detecting malicious USB peripherals in the Cyber-Human-Physical Systems (CHiPS) lab. This research aims to provide authentication for USB devices, to detect and prevent USB-laden attacks. The proposed solution adopts side-channel analysis as its core analysis methodology.
- Began using the new RADICL spaces and equipment to train college students, active professionals, and high school students and teachers in an immersive research environment. Hosted events include the first Idaho Cyber Range Day in April 2023, Computing, Programming, and Engineering merit badges offered to a local Scouting troop, and the Cybercore Advanced Day Camp.

Publications

- (1) Taegan Williams, Tiffany Fuhrmann, and Michael Haney (2022), "Low-cost CTF Platform for Industrial Control Systems Education," 26th Colloquium for Information Systems Security Education (CISSE 2022), 14 November, 2022.
- (2) Tiffany Fuhrmann, Taegan William, and Michael Haney (2022), "Cyber-physical Shooting Gallery: Gamification to Address the IT-OT Gap in Cybersecurity Education," 26th Colloquium for Information Systems Security Education (CISSE 2022), 14 November, 2022.
- (3) R.A. Borrelli, Samuel Root, Porter Throckmorton, Jonathan Tacke, Jacob Benjamin, and Michael Haney, "Cyber Hardening of Nuclear Power Plants with Real-time Nuclear Reactor Operation Simulation," Journal of Progress in Nuclear Energy, (accepted and in revision).
- (4) Sam J. Root, Porter Throckmorton, Jonathan Tacke, Jacob Benjamin, Michael Haney, R. A. Borrelli (2023). Cyber Hardening of Nuclear Power Plants with Real-time Nuclear Reactor Operation – 1. Preliminary Operational Testing. Progress in Nuclear Energy 162, 104742.
- (5) Sam J. Root, Porter Throckmorton, Michael Haney, R. A. Borrelli (2022). Simulated boron shimming cyber-attack on pressurized water reactor. Phoenix, Arizona: Proc., American Nuclear Society Winter Meeting.

Proposals submitted

- (1) R. A. Borrelli (PI), Michael Haney (co-PI) - University of Idaho. Cyber-informed design, education, and training for cyberthreat resiliency with real-time nuclear reactor simulation. University of Idaho. Operation: Resubmission Support. \$34,122. 2022.04.30 - 2022.09.30.
- (2) R. A. Borrelli (PI), Michael Haney (co-PI), Lee Ostrom (co-PI) - University of Idaho. Nuclear Power Plant Cyber-Risk Assessment with Real-Time Reactor Operations. U.S. Nuclear Regulatory Commission Notice of Funding Opportunity (NOFO), Research and Development Grant, Fiscal Year 2023 \$499,036. 2024.06.01- 2027.05.31. [in review]
- (3) Dakota Roberson (PI), R. A. Borrelli (co-PI), Michael Haney (co-PI), Brian Johnson (co-PI) - University of Idaho, Hany Abdel-Khalik (co-PI) – Purdue University, Arthur Deacon (co-PI) - Datacast Technologies, Inc., Steve Bukowski (co-PI) - Idaho National Laboratory. Securing Grid Edge Devices through Distributed Intelligence Synthesis. Department of Energy Cybersecurity, Energy Security, and Emergency Response (CESER). \$2,900,000. 2024.01.01 - 2026.12.31. [in review]

Section 2: High-level summary of budget expenditures for the period just completed. If budget is underspent at time of report, explain why and plans for expending funds.

- Funding of \$693,000 for FY23 is split between UI and co-PIs to manage (\$300,000 subaward to ISU, \$393 allocated to UI.)
- Overall this project remains ahead of schedule and on budget. At the end of the first year of the grant, due to reasons documented and explained in the detailed expenditure report, at the end of the fiscal year, we had \$16,000 that remained unencumbered and was carried forward to year two.
- Student and faculty support, post-doctoral fellow search, and related human capital expenses are all on target.
- Focus during this initial grant reporting period has been on acquisition of equipment, materials, supplies, and renovation of available facilities

During the first year of this grant effort, our focus has been on the renovation of existing laboratory

spaces and acquisition of materials and equipment to enable future training and research. The budget plan explicitly called for the support of one full-time graduate student, and several specific purchases. We have successfully combined our funds with other sources and strategically addressed facilities upgrades, including expanding into an additional laboratory space of 600 square feet for “Balance of Plant” and power substation equipment, which will be connected via networking in the next reporting period. We were also able to engage additional students to support these efforts, as discussed in Section 4 of this report. These resources combined to make our team more successful and ahead of schedule.

Facilities, materials, and equipment under this FY23 HERC IGEN grant specifically fall under one of several categories. In order to support the backbone of our “cyberspace” environment, we have created a private cloud environment to support the reconfigurable virtual spaces for cybersecurity and energy research and training. This was done first through the acquisition of refurbished computing equipment to expand our existing environment. Secondly we had a significant outlay of \$100,000 to purchase new cloud computing equipment. Combined, the computing capacity is many times greater than previously available. Ongoing efforts and support from this grant will be allocated to improve our network equipment connecting our separate lab spaces to one another and to the Idaho Cyber Range.

Next, we focused on the acquisition of the materials and supplies to begin building our “Cyber Shooting Gallery”. This environment will consist of 20 or more platforms of small-scale cyber-physical systems for students to design, attack, defend, and reconfigure. Three initial prototypes have been completed. We are facing significant supply-chain constraints, specifically with the Raspberry Pi computers we hoped to employ, which has forced us to reconsider some design elements. Nonetheless, our initial prototypes were unveiled and met with great enthusiasm at the “BSides Idaho Falls 2022” cybersecurity conference and can be seen in this article: https://www.postregister.com/news/local/more-than-200-attend-idaho-falls-cybersecurity-conference/article_664ec6f2-4666-11ed-a46e-3f8e96e066a2.html

Additionally, we have acquired both information technology (IT) and operations technology (OT) equipment to outfit sixteen student “workstations” that feature state-of-the-art computing capabilities as well as industry-leading cyber-physical control systems. Our spending in this area is complete at \$315,000. The details of this research and training equipment are included in the attached spreadsheets under Section 6 of this report.

The major equipment acquisition for this first year of grant funding was for the RTDS Technologies real-time data simulator for electric grid operations research. This purchase was made possible by \$76,000 from this grant matched by funds from other sources. Additional equipment made available through partnership with Schweitzer Engineering Labs has helped enhance the complexity and realism of simulations for cybersecurity research.

The balance of our expenditures falls either under materials and supplies or salary and related expenses. These expenses are on budget and in accordance with the HERC IGEN requirements and the UI’s Office of Sponsored Programs and are included in the attached spreadsheets under Section 6 of this report.

Section 3: Demonstration of economic development/impact, including the following as applicable: patents, copyrights, plant variety protection certificates received or pending; technology licenses signed, start-up businesses created, and industry involvement; private sector engagement; jobs created; external funding; any other pertinent information.

The initial economic impact of our first year of funding under this HERC IGEM effort can be summarized:

- Multiple journal and conference papers published in initial period.
- Multiple external funding opportunities currently submitted or in development.
- Multiple engagements with private sector partners as well as other academic and research institutions.
- Post-doctoral fellowship positions created to be filled in future reporting period.

External funding has been secured from multiple sources as a result of initial efforts based on this HERC IGEM grant fund, including with the Department of Energy and private partnerships. We have made a significant impact on the national discussion regarding the cybersecurity of the electric grid, as Dr. Roberson was the lead technical contributor to a report to the U.S. House of Representatives, via DOE CESER, on the subject. He has also participated in high-level meetings on the topic representing INL through his joint appointment at the national level and is working to secure further funding to continue growing these efforts at UI-Idaho Falls.

Commercialization efforts of our initial research has begun in the first year. An Idaho-based cybersecurity startup, Datacast Technologies, has begun working on commercializing their product based on the work we are doing in the laboratory and the partnerships developed therein. Curtiss-Wright in Idaho Falls has also expressed interest in collaborating with us towards developing a prototype of our USB monitor setup. They aim to adopt an extension of the concept to test for malicious USB drives inside their airgapped facilities. This collaboration may open opportunities for submitting more proposals.

The co-PIs of this grant are all involved in the ongoing development efforts of the Idaho Cyber Range to make the Idaho Falls-based laboratories and equipment interoperable with research laboratories and training facilities across the state, including at the Idaho National Laboratory's Cybercore Integration Center and the Center for Advanced Energy Studies. Additionally, we are now working with Montana State University on the development of training and education curriculum for hands-on cyber-physical systems security. We have begun regular meetings with industry partners including SEL, Siemens, Intel, Wesco, Western Services Corp, Mickelsen Farms, CLOAKED Cybersecurity, Shadowscape, and CourseOps to form an advisory group for our efforts.

Section 4: Number of faculty and student participants as a result of funding, and brief description of student efforts.

- 1 Master's student directly funded in initial reporting period,
- 1 PhD student directly funded in next reporting period (Spring 23).
- 12 additional undergraduate and graduate students directly involved in supporting initial project efforts.
- 7 principle investigators supported by this grant.

Several students were supported over the course of the project, and most of them have published papers as a result of their efforts. Our students have helped to design, acquire, build, configure, and implement all of our laboratory spaces, capabilities, and equipment described in this report. Future HERC IGEM funding will substantially shift from equipment and materials acquisition to

student education and research involvement by directly supporting multiple graduate students and post-doctoral fellows each year.

Section 5: Updated details and/or progress on the long-term sustainability plan for the project and description of future plans for project continuation or expansion.

- Multiple federal and state grant proposals submitted, under review, or planned (currently over \$8 million under review).
- Multiple levels of engagement with private industry partners for workforce training needs.

The RADICL and related research laboratory and training facilities are designed to enable sustained education, research, and workforce development in Idaho Falls. This involves significant engagement with our industry partners, the Idaho National Laboratory, and the campuses across the state of Idaho connected via the Idaho Cyber Range, as well as through current and planned external funding from federal and state funding agencies. Initial plans for sustained growth and expansion of our capabilities include several grant proposals recently submitted or currently under development. We have also begun development of our model for industry engagement and workforce training opportunities. Recently, the co-PIs, led by Dr. R.A. Borrelli, submitted a robust grant proposal to the National Science Foundation entitled “Cyber-informed Design, Education, and Training for Energy Resiliency with Real-time Nuclear Reactor Operation.” This grant proposal for \$1.2 million will provide for expansion of our nuclear power plant simulation environment, including licensing fees for our current simulator software, expansion of hardware and supporting equipment, and the funding of many students in several disciplines (e.g. computer science, computer engineering, nuclear engineering, electrical engineering) to continue the development of this important platform. The preliminary results necessary to submit a viable NSF grant of this size were made possible by the students and equipment funded during this initial period of the HERC IGEM grant. Additional grant proposals in development and expected to be submitted in the upcoming reporting period include grants led by Dr. Roberson to the Department of Energy’s Nuclear Energy University Programs (NEUP) program (invited proposal for \$800,000), as well as the DoE’s Office of Cybersecurity, Energy Security, and Emergency Response (CESER), by Dr. Koliass to the NSF’s Computer and Information Science and Engineering (CISE) Directorate, and Dr. Haney’s proposals to the Department of Homeland Security and Cybersecurity and Infrastructure Security Agency’s (CISA) programs. The team led by Dr. McBride also has current and planned proposals to the Department of Labor and Department of Education for ongoing workforce development efforts.

We have begun to organize an advisory group to expand on the engagement we have with our community and industry partners across the region. With the development of our multiple spaces, our private cloud computing environment, our shooting gallery, and the data created and collected for running multiple reconfigurable cyber wargame scenarios, we expect to engage and train a wide variety of industry professionals in different roles and critical infrastructure industries. This engagement will allow for a revenue stream to sustain our staff, equipment, software licensing and other operating expenses indefinitely.

Section 6: Expenditure Report – Attach an expenditure report as a separate document showing expenses toward the original budget submitted for this project. The expenditure report does not count toward the page limit. A written summary of budget expenditures should be provided in Section 2 of this report.

Title: ISBOE IGEM HERC: Secure Cyberspace

NO F&A

Funding Agency: IGEM HERC

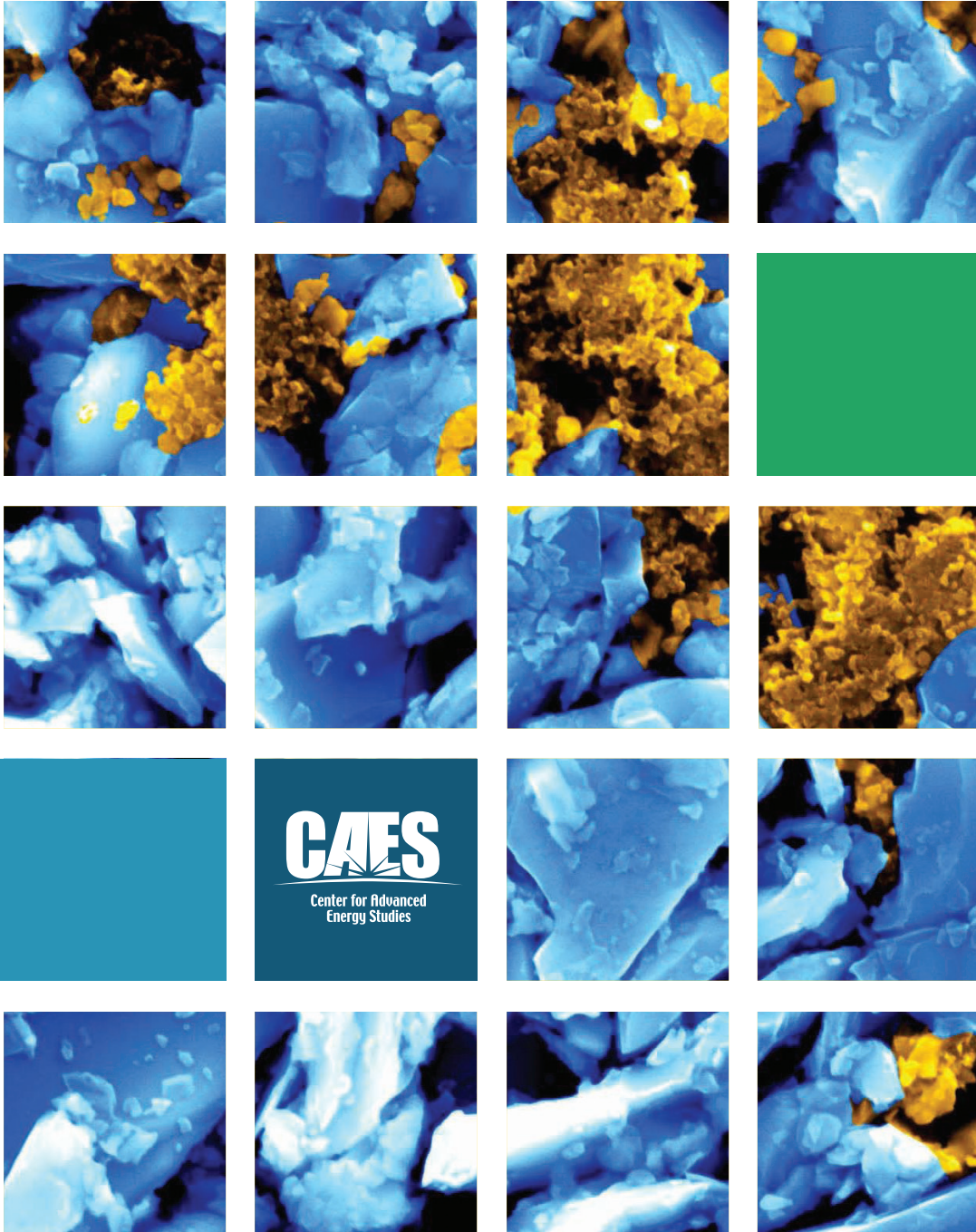
PI: Dr. Michael Haney

			Commitments as of 07/31/2023
Budget Category	Budget	Activity	
10 - Senior/Key Personnel	\$35,517.54	\$30,341.25	\$0.00
Faculty - Academic Year - Dr. Haney			
Faculty - Summer - Dr. Haney			
Faculty - Academic Year - Dr. Borrelli			
Faculty - Summer - Dr. Borrelli			
Faculty - Academic Year - Dr. Roberson			
Faculty - Summer - Dr. Roberson			
Faculty - Academic Year - Dr. Kolias			
Faculty - Summer - Dr. Kolias			
Other Personnel	\$15,195.40	\$15,195.40	\$0.00
Grad Student - Academic Year (G. Makrakis)			
Grad Student - Academic Year (T. Williams)			
12 - Irregular Help	\$12,289.92	\$4,407.48	\$0.00
Grad Student - Summer (J. Tacke)			
Grad Student - Summer (G.Makrakis)			
11 - Fringe	\$11,466.21	\$9,852.30	\$0.00
Fringe - Faculty - Academic Year			
Fringe - Faculty - Summer			
Fringe - Grad Student - Academic Year			
Fringe - Grad Student - Summer			
30 - Operating Expenses	\$39,133.52	\$39,438.24	\$318.36
40 - Capital	\$189,765.52	\$110,547.32	\$76,051.95
45 - Small Equipment	\$78,487.89	\$67,580.71	\$7,902.44

70 - Tuition	\$11,144.00	\$11,144.00	\$0.00
Subaward with Idaho State University	\$300,000.00	\$155,817.32	\$144,182.68
Total Direct and Indirects Costs	\$693,000.00	\$444,324.02	\$228,455.43

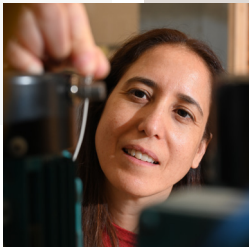
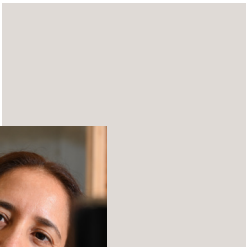
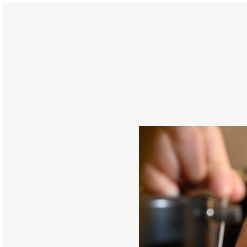
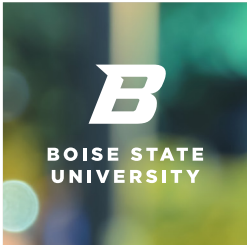
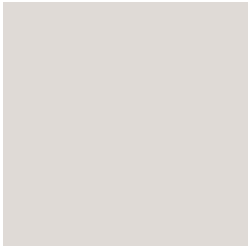
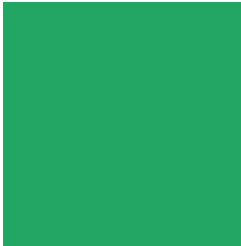
Available 07/31/2023	# Hrs	# Students	\$/Hr	Budget Remaining	Total
\$5,176.29	0.00		\$0.00	\$0.00	\$0.00
	0.00		\$0.00	\$0.00	\$0.00
	0.00		\$0.00	\$0.00	\$0.00
	0.00		\$0.00	\$0.00	\$0.00
	0.00		\$0.00	\$0.00	\$0.00
	80.00		\$64.69	\$5,175.20	\$5,175.20
	0.00		\$0.00	\$0.00	\$0.00
	0.00		\$0.00	\$0.00	\$0.00
\$0.00	0.00	0	\$24.00	\$0.00	\$0.00
	0.00	0	\$20.41	\$0.00	\$0.00
\$7,882.44	160.00	1	\$20.79	\$3,326.40	\$3,326.40
	0.00	1	\$24.00	\$0.00	\$0.00
\$1,613.91	31.0%			\$0.00	\$0.00
	31.0%			\$1,604.31	\$1,604.31
	2.5%			\$0.00	\$0.00
	2.5%			\$83.16	\$83.16
-\$623.08				\$0.00	\$0.00
\$3,166.25				\$0.00	\$0.00
\$3,004.74				\$10,031.48	\$10,031.48

\$0.00	\$0.00	\$0.00
\$0.00	\$0.00	\$0.00
\$20,220.55	\$20,220.55	\$20,220.55
		\$0.00



CENTER FOR ADVANCED ENERGY STUDIES
2022 ANNUAL REPORT

This report provides an overview of the main accomplishments of the CAES community in FY22.



On the cover, the photo is a microscopic view of batteries from research conducted by an Idaho National Laboratory researcher—one of the four entities collaborating with CAES.

DIRECTOR'S LETTER

IT HAS BECOME CLEAR IN MY RELATIVELY SHORT TIME AT THE CENTER FOR ADVANCED ENERGY STUDIES that the integrity and professionalism of those involved with CAES, from the students to the maintenance crew, are admirable. A second revelation has been the receptiveness to collaboration. This is the key to CAES' success and the reason for its existence; the willingness to work together is exciting and important to the continued success of CAES. In the coming months, I will work with the associate directors, the universities and the national laboratory to explore how we can harness this willingness to collaborate. The focus of this effort will be twofold: to bring more students and researchers into the building and to refine the CAES Strategy into areas where our collaborative efforts can have the most impact.

As you will see in this report, our impact in 2022 was extensive. We saw the introduction of the Research Experience for Undergraduates program and the 10 REU fellows who participated over the summer. We also saw the resumption of the in-person Center for Space Nuclear Research Summer Fellowship Program after the program went virtual for two years due to the pandemic. These are examples of experiential learning that we look to replicate and expand in the years ahead.

We're also working to develop a sense of community at CAES. The goal is to not only make CAES a great place to conduct research, with state-of-the-art tools and equipment, but also to create a welcoming environment that makes it a great place to work. On that front, we are working with Idaho State University to open the parking lot to food trucks. This will facilitate networking among the CAES community. And we're working on an in-house newsletter to ensure CAES residents are better informed about upcoming events and research news.



There are many exciting developments on the horizon and many to celebrate in this year's annual report. CAES researchers are receiving financial support, as well as recognition at the state and national levels. We installed new state-of-the-art equipment that will increase the opportunities for collaboration in the years to come and initiated new programs while building on others. Those are just a few of the accomplishments outlined in this report — accomplishments that make me proud to be part of this consortium.

I look forward to working with all of you as we transform the culture at CAES, to improve and expand our collaborative opportunities while fulfilling our mission and vision.

In the meantime, I welcome your ideas for improving the way things are done around here. My door is always open.

Philip Reppert
*Center for Advanced Energy
Studies director*

CONTENTS

- 1 New faces
- 2 News
- 8 Accolades
- 14 Highlights
- 21 Events
- 24 Meetings, open houses, seminars and speeches
- 27 Publications and proceedings

NEW FACES

New CAES director announced



Philip Reppert was named director of Idaho University Collaborations and CAES in April. Reppert was previously the associate director of

Geological and Environmental Systems at the National Energy Technology Laboratory. There, he provided technical leadership and capability stewardship for a complex organization with three teams/branches who conduct research in the earth sciences. Prior to that, Reppert spent seven years at the National Geospatial-Intelligence Agency as a senior project scientist and supervisor of the geophysics subsurface research branch.

In addition to serving as CAES director, Reppert oversees collaboration between Idaho National Laboratory and the CAES universities.

Reppert earned a bachelor's degree in Electrical Engineering from Pennsylvania State University and a doctorate in Geophysics from the Massachusetts Institute of Technology. Reppert has a distinguished research background in near-surface geophysics and ground-penetrating radar, as well as rock physics.

Reppert took over for Terry Brog, who had served as interim CAES director since fall 2020. We thank Brog for his work as interim director, particularly his effort to streamline operations at CAES during the pandemic. His leadership has helped us get researchers into the laboratories.

CAES steering committee gains new member as ISU names VPR

Idaho State University named **Martin Blair** as vice president for research (VPR) in June. As VPR, Blair joins INL Deputy Laboratory Director for Science and Technology and Chief Research Officer Marianne Walck, CAES Director Philip Reppert, Boise State Vice President of Research and Economic Development Nancy Glenn and University of Idaho Vice President for Research and Economic Development Christopher Nomura on the CAES steering committee.

Prior to his arrival at ISU, Blair served as executive director at the University of Montana's Rural Institute for Inclusive Communities, responsible for developing



community-focused interdisciplinary research partnerships, overseeing strategic planning and managing a multi-million dollar budget across more than 50 programs.

Blair earned a bachelor's degree in Special Education, a master's degree in Secondary Education and a doctorate in Education and Disability Policy from Utah State University. He also earned certifications from the National Leadership Institute at the University of Delaware and CITI: Social and Behavioral Research.

Kiyo Fujimoto named lab lead



INL researcher **Kiyo Fujimoto** was named lab lead for the Advanced Manufacturing Suite this fall. Fujimoto received her PhD in Materials Science and Engineering from Boise State University in the spring. She has been involved with INL since 2017, when she was an INL Graduate Fellow, and is now a staff scientist leading research focused on additive manufacturing methods for the development of advanced sensors and instrumentation for extreme environments.

Fujimoto earned a bachelor's degree in Chemistry from Boise State. In addition to receiving an INL Graduate Fellowship, she is the recipient of the Idaho Space Grant Consortium Fellowship and the Department of Energy Nuclear Energy University Partnerships Fellowship. At INL, her work is focused on materials development or feedstock synthesis relevant to harsh environments for a wide range of additive manufacturing techniques.

BSU names Glenn VPR after serving as interim



Nancy Glenn was named vice president for research and economic development (VPR) for Boise State University in September.

Glenn, a professor in the Department of

Geosciences, had served as interim VPR since June 2021.

Glenn earned a bachelor's degree in Geological Engineering from University of Nevada, Reno; a master's degree in Civil Engineering from University of California, Berkeley; and a PhD in Geo-Engineering from University of Nevada, Reno.

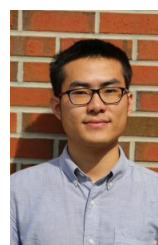
New professors at UI



Krishnan Raja, a Chemical and Materials Engineering Department faculty member, joined UI, Idaho Falls as a visiting faculty member.

Ming-Hsun Cheng joined UI, Idaho Falls as an assistant professor for Energy & Environment.

Microscopy & Characterization Suite adds to staff



Yu Lu (top left) is a senior research associate and instrument lead. **Sidharth (Sid) Sukumaran Nair** (top right) is a research associate and sample preparation lead. Ching-Heng Shiau is a postdoctoral researcher.

Interns

Nahuel Guaita was CAES' Programmatic graduate intern over the summer and fall, as he was completing his master's degree in Public Policy, with a concentration in Energy and Environmental Policy, from Oregon State University.

Undergraduates

Mia Rudin is a student at University of Texas at Dallas, where she is majoring in Geological and Earth Sciences/Geosciences.

Leah Alboucq is a student at Boise State University, where she is majoring in Health Studies.



CAES universities sign MOU for full access to Falcon supercomputer

Researchers at the CAES universities have exclusive access to the Falcon supercomputer, one of the nation's fastest academic computers, thanks to an agreement signed in mid-January. The memorandum of understanding between

the universities and Battelle Energy Alliance provides students and researchers from the universities unfettered access to the computer, which is located at Idaho National Laboratory's Collaborative Computing Center in Idaho Falls. The arrangement has also increased

opportunities for collaboration between INL researchers and those at the universities. This investment in INL's future fulfills a CAES mission of training and educating the future energy workforce.

BSU's Nuclear Energy Student Club formally recognized by American Nuclear Society

The American Nuclear Society board approved the creation of a new student section at Boise State University in May. Assistant professor Brian Jaques, a CAES fellow, serves as the group's faculty adviser.

"This is a great opportunity for students to engage and network with other sections in the state of Idaho, as well as nationally and internationally," said Jaques, who holds a joint appointment with INL. "The section brings awareness and excitement

of Idaho's rich nuclear energy history to the community, in addition to introducing our future nuclear energy workforce to the vast opportunity and promise of the field."

CAES hosts NSF Research Experience for Undergraduate (REU) program

Ten students took part in the inaugural REU program, "Advanced Manufacturing for a Sustainable Energy Future," at CAES over the summer. A \$365,000 grant from the National Science Foundation led to the creation of the program, which will run 10 weeks each summer through 2024. The program is designed to give students hands-on research experiences and networking opportunities to develop their science, technology, engineering and math identity and literacy, while providing professional development opportunities for careers in the energy sector.

Five students from Idaho's two- and four-year higher-education institutions were in the inaugural cohort this year, along with five students selected from a pool of applicants from across the nation. The students worked alongside faculty from the CAES universities and Idaho National Laboratory researchers to assist on projects related to advanced manufacturing.



Here are the REU fellows along with their project titles and mentors:

Lydia Beardsley
University of Idaho

PROJECT: Development of High-Temperature Resistant Permanent Magnets Using Advanced Manufacturing

MENTORS: Dan LaBrier, Idaho State University (faculty) and Bryce Kelly (INL)

Miranda Cardenas
University of Utah

PROJECT: Multiphysics Modeling and Experimental Characterization of Printed Magnetostrictive Acoustic Sensors

MENTORS: Dan Deng, Boise State University (faculty) and Josh Daw (INL)

Dylan Cox
Oregon State University
and Katelyn Shadley
University of Idaho

PROJECT: 3D Li-ion Batteries through Advanced Manufacturing

MENTORS: Claire Xiong, Boise State University (faculty) and Bin Li (INL)

Stratton Jenks
University of Idaho
and Josh Peck
Idaho State University

PROJECT: Advanced Manufacturing for Bulk Storage of Hydrogen

MENTORS: Mustafa Mashal & Bruce Savage, Idaho State University (faculty) and Kunal Mondal (INL)

Minh Nguyen
Idaho State University

PROJECT: Novel Alloy Development for Nuclear Applications

MENTORS: Brian Jaques, Boise State University (faculty) and Boone Beausoleil (INL)

Hayden Pritchard
University of Montana

PROJECT: Corrosion Performance of Additively Manufactured Structured Materials

MENTORS: Mike Hurley, Boise State University (faculty) and Donna Guillen (INL)

Avery Rambur
College of Idaho

PROJECT: Classical Molecular Dynamics Simulations of Nuclear Materials

MENTORS: John Russell, University of Idaho (faculty) and TBD (INL)

Hannah Smith
University of Utah

PROJECT: Modeling and Optimization of Advanced Manufacturing Processes

MENTORS: Lan Li, Boise State University (faculty) and Michael McMurtrey (INL)



New 3D metal printer installed at CAES as Advanced Manufacturing Laboratory takes shape

A new 3D metal printer for nuclear-grade materials was installed at CAES over the summer, one of several pieces of equipment that complement Idaho National Laboratory's advanced manufacturing strategy, accelerating and supporting INL's research and development capabilities as well as its partnerships with academia, industry, federal agencies and national laboratories through the Nuclear Science User Facilities network. The printer, part of approximately \$1.5 million in equipment installed in the new Advanced Manufacturing Laboratory at CAES, was made possible by a 2020 award through the Nuclear Energy University Program for a project led by Boise State University faculty member Mike Hurley. The project stems from Hurley's participation in the 2019 CAES Summer Visiting Faculty Program and includes his faculty program partner Donna Guillen from INL and Boise State faculty members and fellow 2019 faculty program alumni Dave Estrada, who is the CAES associate director for Boise State, and CAES Fellow Brian Jaques, the CAES Advanced Manufacturing lead at Boise State.

The printer is an Open Additive PANDA with a 6x6x4-inch build volume, 300 W laser and production print speeds that is capable of printing stainless steels, super alloys and tool steels.

The equipment in the new Advanced Manufacturing Laboratory supports materials development, printed sensors and structural additive manufacturing from INL and the CAES universities, while supporting existing programs and opening new areas in printed and flexible electronics and trusted artificial intelligence for advanced manufacturing. The Advanced Manufacturing Laboratory is managed as a shared resource benefitting the CAES

universities, multiple INL mission areas and several directorates at INL, including Nuclear Science & Technology, Energy & Environment Science & Technology, National and Homeland Security, Advanced Test Reactor and Materials and Fuels Complex.

The laboratory is complemented by a new ThermoFisher Spectra 300 scanning transmission electron microscope in CAES's Atomic-Scale Imaging Laboratory, part of the Material and Characterization Suite, that is capable of doing post irradiation examination of printed structural materials and sensors.

Equipment in the new Advanced Manufacturing Laboratory includes a

Superinkjet printer and Nanojet aerosol jet printer capable of printing sensors as well as:

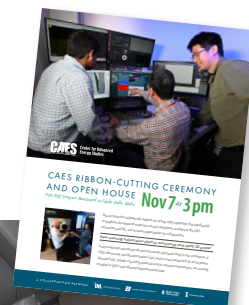
- Mills for powder production, including a Torrey Hills three-roll mill, Retsch Emax high energy ball mill, Retsch mortar and pestle mill, Retsch cronimil
- High precision scales
- Zeiss Axio imager KMAT (an upright, fully motorized, PC controlled, high performance research microscope)
- Particle size analyzer w/zeta potential measurement
- Rotary evaporators
- Planetary centrifuge
- Anton Paar dynamic mechanical analyzer and rheometer

CAES debuts new scanning transmission electron microscope

CAES officially debuted a new scanning transmission electron microscope (S-TEM) in late July. The ThermoFisher FEI Spectra 300 kV S-TEM is Idaho National Laboratory's latest investment in CAES, designed to create opportunities for collaborative materials research for the CAES universities, INL and industry in several of the national laboratory's mission areas. The new microscope is part of the Microscopy and Characterization Suite, a Nuclear Science User Facilities laboratory, and is more technologically advanced than any of the current TEM resources across the CAES complex. Among its capabilities:

- The new S-TEM offers an energy resolution of less than 0.2 eV compared to 0.8 eV with current TEMs at INL
- It enables the study of stoichiometry changes in oxide fuels, chemistry of fission products in nuclear fuels, and oxidation/corrosion behavior of metals and ceramics
- It is equipped with a next-generation Cs S-CORR probe corrector
- It provides improved spatial resolution at low accelerating voltages, enabling analysis of light elements (carbon, nitrogen and oxygen for example)
- It enables research on a wider range of materials, from those that are sensitive to high-energy electron beams to high atomic number materials such as uranium
- It is equipped with an EMPAD detector, which can obtain more than 1,000 diffraction patterns per second
- It captures dynamic material behavior such as phase changes and crystallization in harsh environments
- It has a broader electron energy range (30kV-300kV) for characterization than current TEMs in the CAES complex (80kV – 200kV)
- It is equipped with a double-corrector (probe and image) configuration
- It is capable of achieving point-resolution close in value to the information limit of the system

CAES celebrated the S-TEM and 3D Metal Printer at a ribbon-cutting ceremony.



Center for Space Nuclear Research Summer Fellowship Program returns to CAES

CAES welcomed the summer fellows for the Center for Space Nuclear Research in June – the first year the fellowship has been held in person since 2019. Stephen Herring, the center's director, led the program virtually in 2020 and 2021.

Each summer, the center, which is housed at CAES, invites a group of undergraduate and graduate students from across the country to learn about cutting-edge research in nuclear power and propulsion technologies through its Summer Fellowship Program. The program runs for 10 weeks and allows the fellows to work as a team, in partnership with Idaho National Laboratory researchers, to complete a research project of interest to NASA in potential nuclear technology performance. The Summer Fellowship Program allows participants to experience a real research environment, to learn from nuclear scientists and to preview careers in research. This year, those accepted as fellows had the option of participating in person or virtually. Nine students attended in person while two participated online.

Here are the fellows and the schools they attend:

Zyed Ansary
University of Denver

Daniel John Black
Brigham Young University-Idaho

Aanchal Gupta
University of Illinois Urbana-Champaign

Kaasturi Khatun
University of Southern California

Kean Martinic
Idaho State University

Arnold Pradhan
University of Idaho

Berenice Sosa Aispuro
Idaho State University

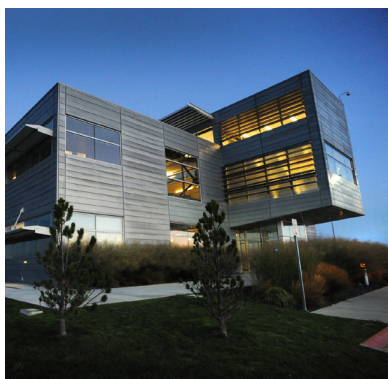
Daniel Watson
Texas A&M

Teyen Widdicombe
University of Idaho

Participating online

Manikandan Pandiyan
University of Michigan

Bikash Parajuli
University of Akron



Did you know?

Idaho National Laboratory and the Universities Space Research Association created the Center for Space Nuclear Research in 2005 to foster collaboration between the lab and university scientists. The center's scientists and engineers research and develop advanced space nuclear systems, including power systems, nuclear thermal propulsion and radioisotopic generators.

State legislature approves funding for Nuclear Engineering program

The Idaho Legislature approved \$1.1 million to support the joint Nuclear Engineering program offered by Idaho State University and University of Idaho, a move that will allow for expansion of the program's faculty. The partnership between the two CAES universities demonstrates the state Board of Education's push for collaboration between Idaho's public universities and colleges. Students enrolled at either of the universities can take classes at the other university, either at physical campuses or online, and collaborate with Idaho National Laboratory researchers. As of spring 2022, more than 200 students from UI were enrolled at the Idaho Falls campus, and 974 ISU students were enrolled both online and on campus.





CAES hosts open house

Approximately 100 affiliates of CAES – students, faculty and INL researchers – attended an open house at CAES in mid-September. The event featured tours of the facility, a poster session and demonstrations in the Applied Visualization Laboratory and the Small Modular Reactor Simulator Laboratory, which features a simulator of the control room for a NuScale small modular reactor. The open house offered a chance for the affiliates to bring their families and network with other members of the CAES community.



ACCOLADES



National Science Foundation Scholarships in STEM program award

National Science Foundation Scholarships in STEM program award of \$5 million went to Boise State University to help students from historically underserved backgrounds.

CAES' involvement focuses on designing a Scholars Seminar to help establish networks, provide skills-based training and highlight career opportunities. *Read more on this page.*

Higher Education Research Council- Idaho Global Entrepreneurial Mission

The Higher Education Research Council-Idaho Global Entrepreneurial Mission awarded \$2.1 million over three years to a team led by University of Idaho's Michael Haney for a project that calls for creating an immersive training environment for students across Idaho.

The award will lead to a project at CAES called Secure Cyberspace and Resilient Industrial Systems Workforce Development, a physical lab that ties into an existing simulator at the Applied Visualization Laboratory that focuses on



cybersecurity for the nuclear industry and infrastructure. *Read more on page 11.*

Nuclear Regulatory Commission grant

The Nuclear Regulatory Commission (NRC) awarded a \$450,000 Faculty Development Grant to Idaho State University faculty member Amir Ali.

Ali, the lab lead for CAES' Innovation Laboratory, plans to use the award to create a program enabling thermal hydraulic research at ISU. *Read more on page 9.*

Idaho Global Entrepreneurial Mission award

Idaho Global Entrepreneurial Mission awarded \$348,000 to University of Idaho assistant professor Amin Mirkouei and industry partner Idaho Strategic Resources to research and develop a new technique for drilling and extracting rare earth elements. The project includes researchers from INL, CAES and the state of Idaho. *Read more on page 13.*

Boise State receives NSF award to establish CAES Scholars Consortium

 A \$5 million award from the National Science Foundation's Scholarships in STEM program will enable Boise State University to create a statewide academic consortium with the College of Southern Idaho and the College of Western Idaho. Boise State's award will fund scholarships for more than 150 students pursuing degrees in electrical and computer engineering. The goal is to address the nation's need for scientists, mathematicians, engineers and researchers. CAES' role will be to create a Scholars Consortium to assist first-year students at the colleges prepare for careers in science, technology, engineering and math fields with targeted mentorship, self-discovery, and development of their career aptitude and professional identity.

UI, ISU team gets grant to create immersive cybersecurity training

A team led by University of Idaho faculty member **Michael Haney** received a \$2.1 million award from the Higher Education Research Council-Idaho Global Entrepreneurial Mission (HERC-IGEM) for a project that calls for creating an immersive training environment for cybersecurity students statewide.

The project, Reconfigurable Attack-Defend Instructional Computing Laboratory (RADICL) at the University of Idaho's Idaho Falls Center for Higher Education, will be available to students at any Idaho university. The project will provide access to what will eventually be a hybrid physical/virtual environment through the Idaho Regional Optical Network, a high-speed optical network that connects higher education institutions, health care organizations, government agencies and not-for-profit organizations throughout the state. It expands on the RADICL facility on University of Idaho's main campus in

Moscow, which provides hands-on teaching and research in the areas of information assurance, cyber defense, and modern computing platforms and networks. The new effort will include cyber-physical systems and operations technology for critical infrastructure. The immersive environment created by the project will mimic real-world activity on the internet – "Things you couldn't do in a classroom," said Haney, associate professor of computer science for the University of Idaho and a cybersecurity researcher at Idaho National Laboratory.

Led by Haney, the project includes UI researchers R.A. Borrelli, Dakota Roberson and Constantinos Kolias, and Idaho State University researchers Benjamin Lampe, Sean McBride and Ryan Lind.

The HERC-IGEM program, which is designed to stimulate competitive research at Idaho's higher education institutions, will fund the project for three years at \$693,000 annually.



Projects selected for funding must align with the statewide higher education research strategic plan. Haney's project aligns with the

plan to boost cybersecurity education at the state's universities and colleges through a private fiber-optic network that connects classrooms and research laboratories on all of Idaho's public higher education institutions. The goal is to eventually incorporate CAES and INL's Collaborative Computing Center and Cybercore into the plan. At CAES, Haney plans a project called Secure Cyberspace and Resilient Industrial Systems Workforce Development, a physical lab that ties into an existing simulator at the Applied Visualization Laboratory and focuses on cybersecurity for the nuclear industry and infrastructure.

ISU's Nuclear Engineering Program receives NRC grant

 Idaho State University's Nuclear Engineering Program received a \$450,000 grant from the Nuclear Regulatory Commission through the Faculty Development Grant program to support assistant professor **Amir Ali's** research program.

The NRC program provides support for education in nuclear science, engineering and related trades to develop a workforce capable of designing, constructing, operating and regulating nuclear facilities and safely handling nuclear materials. The grant is for faculty members in the first four years of their career and is intended



to support faculty development under supervision by a mentor.

Ali, who leads the Innovation

Laboratory at CAES, plans to use the award to create a program enabling thermal hydraulic research in ISU's Nuclear Engineering Department.

"We've never had that at ISU," Ali said, adding that the new program will meet a "strong need" from Idaho National Laboratory.

The program Ali is developing under the mentorship of Chad Pope – a professor, Nuclear Engineering program director at ISU, and principal investigator on the grant – will feature two to three courses, one on computational thermal hydraulics and another on fire protection systems for nuclear applications.

Ali's award will most immediately impact CAES through the introduction of research on the fission gas release phenomenon in advanced reactors.

Researchers from ISU, BSU receive DOE grants for projects involving INL

Two projects involving Idaho National Laboratory and CAES universities were among 29 projects that received a total of \$21 million through the Department of Energy's Established Program to Stimulate Competitive Research (EPSCoR) program in September.

Idaho State University's Cori Jenkins, an assistant professor of chemistry, and ISU colleague Josh Pak were recipients of an EPSCoR award in collaboration with INL researcher Simon Pimblott, in the Nuclear Science and Technology directorate. The project, "Mechanistic and Kinetic Analysis of Polymer Deconstruction and Modification by Irradiation for Polymer Upcycling," developed in part from an ISU-CAES seed grant also involving INL researchers. ISU awards seed grants to collaborative research projects involving partners from INL and the other CAES universities, with funding from the portion of ISU's annual state funding allocated for CAES activities.

Boise State University's Kurtis Cantley, an associate professor of electrical and computer engineering, received EPSCoR funding for a project called "Neuromorphic Systems for Power Grid Cyber-Resilience," on which he is collaborating with researcher Craig Rieger in INL's National and Homeland Security directorate.

DOE's EPSCoR program is designed to enhance the capabilities of states and territories to conduct sustainable and nationally competitive energy-related research. Twenty-five states, including Idaho, plus Puerto Rico, Guam and the U.S. Virgin Islands are eligible to participate in the program, which pairs innovative ideas from

EPSCoR-eligible institutions with leading-edge capabilities at national laboratories. The goal is to enhance research while building expertise and capabilities that will enable the institutions to better compete for other federal research and development funding, while advancing the geographic diversity of researchers conducting competitive energy-related research.

"The EPSCoR program is a long-standing and critical pillar in the Department of Energy's efforts to ensure that all regions

and institutions, particularly those that have been historically underrepresented in federal research funding programs, are engaged in competitive, impactful, clean-energy-relevant research," Asmeret Asefaw Berhe, director of the DOE Office of Science, said in a news release announcing the awards. "The projects selected for awards will help to build expertise and capabilities at the EPSCoR institutions and will strengthen their connections to the wealth of capabilities at the DOE national laboratories."

CAES Fellow Mustafa Mashal receives two fellowships



Mustafa Mashal, a CAES fellow and associate professor in the Department of Civil and Environmental Engineering at ISU,

received the Fulbright U.S. Scholar Award and the University of Canterbury's Visiting Erskine Fellowship this year.

For his Fulbright award, Mashal is spending 10 months at Qatar University in Doha, Qatar, conducting research on the use of titanium alloy bars to retrofit structurally deficient concrete buildings, teaching a graduate-level class on precast concrete and providing seminars and training sessions.

Prior to his Fulbright program, Mashal spent four months at the University of Canterbury for the Visiting Erskine Fellowship, teaching a class on designing and retrofitting reinforced concrete bridges to withstand earthquakes, and he collaborated with the faculty on research projects.

Mashal, a member of the initial cohort of CAES Fellows, received a \$1.1 million award through the Idaho Global Entrepreneurial Mission in 2019 for a project that led to the construction of the Disaster Response Complex on ISU's campus in Pocatello. Mashal collaborated with INL researcher Bryon Marsh on the project. Their collaboration dates to a CAES Collaboration meeting in 2018.

Boise State faculty member on team awarded NEUP grant

CAES Fellow **Brian Jaques** of Boise State University is among the researchers involved in a project that received a \$300K grant via the Nuclear Energy University Program. Led by a researcher from the University of Texas at San Antonio, the project supports the fabrication and testing of advanced nuclear fuels and materials, specifically the development of uranium-bearing compounds, alloys and composites. Jaques, an assistant professor of Materials Science and Engineering, is a frequent collaborator



with Idaho National Laboratory researchers in the High Temperature Test Laboratory, Transient Reactor Test Facility and the Advanced

Test Reactor on the In-Pile Instrumentation Program. He is also the Boise State representative in CAES' effort to collaborate with ATR for student engagement.

ISU faculty member, CAES resident, awarded NASA fellowship



Dan LaBrier, an assistant professor of nuclear engineering at Idaho State University and a CAES resident, was recently awarded

an Idaho NASA Established Program to Stimulate Competitive Research (EPSCoR) Summer Faculty Fellowship.

The fellowship program supports Idaho-based faculty in their efforts to better align their research programs with topical areas and missions that NASA leads, offering participating faculty members time and resources to analyze and understand NASA's needs and examine how their research and expertise might meet those needs.

Fellows are introduced to resources such as the NASA Solicitation and Proposal Integrated Review and Evaluation System, the 2020 NASA Technology Taxonomy, the NASA Human Research Roadmap and TechPort, and the opportunity to meet with the Idaho NASA EPSCoR team to better understand processes.

CAES fellow part of team that lands NSF grant



CAES Fellow **Claire Xiong** from Boise State University is a member of a research team that received a grant of nearly \$2 million from the National Science Foundation to engage prospective elementary teachers' mathematical learning through science, technology, engineering and math (STEM) inquiry and experiential learning. The goal of the research is to improve prospective elementary teachers' engagement through innovative, interdisciplinary and inquiry-based approaches to address the pressing needs for integration of multiple disciplines in



STEM education. The grant will empower interdisciplinary collaboration across STEM fields, including mathematics, computer science, and

materials science and engineering, across four universities: Boise State, Augusta University, the University of Texas at San Antonio, and Kapi'olani Community College. Xiong is an associate professor of materials science and engineering at Boise State.

INL researcher, ISU faculty member, named to statewide Accomplished Under 40 list

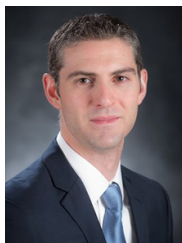


Idaho National Laboratory researcher **Kunal Mondal**, an affiliate faculty member in Idaho State University's Department of

Civil and Environmental Engineering, was recognized by Idaho Business Review's Accomplished Under 40. The publication awards the title each year to 40 people selected by a panel for their

"exceptional work ethic and leadership in both government and private sector organizations." Mondal, in INL's Energy and Environment Science and Technology directorate, has collaborated often with CAES Fellow Mustafa Mashal, an ISU associate professor, to advance the field of materials science. Mondal's research focus is micro/nano fabrication of functional materials, soft and stretchable electronics, and carbon nanomaterials.

University of Idaho faculty member leads team that received NSF EPSCoR award



University of Idaho faculty member **Michael Maughan** leads a research team that received a \$3.9 million Research Infrastructure

Improvement Track-2 Focused Established Program to Stimulate Competitive Research (EPSCoR) Collaboration award from the

National Science Foundation's Office of Integrative Activities. The project calls for teams from UI and Auburn University to create a framework to utilize renewable and waste feedstocks to develop 100% bio-based materials for the Advanced Housing Manufacturing Industry of the Future. The project includes outreach to high school chemistry students, undergraduate and graduate student education, and mentoring

postdoctoral scholars and early-career faculty members. The two NSF EPSCoR states involved in the project, Idaho and Alabama, are expected to benefit economically from industry partnerships and technology developments that emerge from it. Maughan is an assistant professor in the Advanced Manufacturing and Material Properties Group at UI and a member of the 2021 cohort of the CAES Summer Visiting Faculty Program.

BSU faculty receives multimillion-dollar research grant from US Air Force



The Boise State University Advanced Nanomaterials and Manufacturing Laboratory and NextFlex, a Department of Defense-sponsored

Manufacturing USA institute, received a \$4.3 million grant from the Air Force Research Laboratory at Wright-Patterson Air Force Base to enable advanced manufacturing of flexible hybrid electronics using mixed dimensional materials.

Dave Estrada, the CAES associate director for BSU and associate professor in the Micron School of Materials Science and Engineering, leads the effort to enable the fundamental science necessary to expedite the manufacturing, maintenance and repair of sensors and systems critical to ensuring global persistent awareness, resilient information sharing, and the speed and reach of U.S. Air Force missions.

"This award will position our team to advance semiconductor manufacturing techniques that may currently not be well suited for processing atomically thin films," said Estrada.



UI faculty member tours French nuclear plants

CAES Fellow Haiyan Zhao visited several nuclear sites in France during a visit arranged through the French section of the American Nuclear Society. Zhao is an associate professor in the Chemical and Biological Engineering Department and affiliated faculty in the Nuclear Engineering and Environmental Science program at University of Idaho, Idaho Falls.

Over seven days in July, she crisscrossed France to tour nuclear facilities such as Cadarache, the largest technological research and development center for energy in Europe that hosts several research reactors; La Hague, a nuclear fuel reprocessing plant; Andra LLW waste storage site; and Marcoule Nuclear Site.

"It was really eye-opening to see how the French government, industry and the public respond to challenges and work together," Zhao said. She came away from the trip with valuable information about how the country handles the nuclear fuel cycle, from the front-end of preparing material for reactors to the back end of safely preparing, managing and disposing of the radioactive spent nuclear fuel.

Zhao was joined on the trip by eight professors from across the U.S. She applied for and was selected to participate in the journey in 2020. The event was delayed until this year due to the COVID-19 pandemic.

CAES students receive accolades

Two of the students who participated in the CAES Research Experience for Undergraduates (REU): Advanced Manufacturing for a Sustainable Energy Future program this summer received awards for their work. Hannah Smith was one of 10 REU students in the nation selected to present at the Engineering Education Conference, held in Washington, D.C., in September. Miranda Cardenas was awarded the University of Utah's Virginia Lee Beecraft Scholarship for a personal statement she wrote on her REU experience that discussed her background and the impact

she hopes to make through her work in advanced manufacturing. The scholarship is awarded to a student who demonstrates creativity, resilience and a desire to positively impact the world. In addition, REU Program Coordinator Hillary Fishler, who is CAES' programmatic lead, was selected to present professional development tools and strategies developed for the program at the Engineering Education Conference.

CAES fellows' team wins INL competition

Several members of the inaugural cohort of CAES's Research Experience for Undergraduates: Advanced Manufacturing for a Sustainable Energy Future program are also members of a team that won Idaho National Laboratory's Innovation Week 2022 Net-Zero Collaboration Challenge. Lydia Beardsley, Miranda Cardenas, Dylan Cox, Hayden Pritchard, Avery Rambur, Katelyn Shadley and Hannah Smith joined INL intern Kari Perry to win the challenge for their proposal, "Bike Commuter Resource Center." The team received 160 hours of time to develop the project, which addresses the lack of bike accessibility in Idaho Falls and offers an innovative solution that includes education, information availability and community development to encourage INL employees to reduce their carbon emissions by biking to work. Contest organizers said the team's proposal has the potential to significantly reduce emissions related to employee commuting, which makes up 12% of INL's total carbon emissions, while improving biker safety and enhancing employee health and well-being.

University of Idaho projects win IGEM awards

Several projects with CAES connections won awards through the Idaho Global Entrepreneurial Mission, a grant program that funds research projects in which faculty members from CAES universities collaborate with industry to bring viable technologies to market.

HempWool project



University of Idaho received a \$206,000 grant from IGEM to collaborate with industry partner Hempitecture Inc. to research and develop

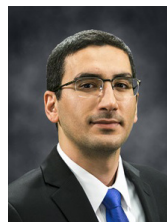
a natural fiber insulation product. The goal is to develop the product, called HempWool, into a pioneering sustainable product in the building industry.

"This innovation means exciting changes to the building industry in Idaho and beyond," said Tom Kealey, director of the Idaho Department of Commerce, which awards IGEM grants. "We are excited to see this public-private partnership between Hempitecture Inc. and the University of Idaho."

The UI team is composed of several researchers in the university's College of Natural Resources and includes **Damon Woods**, interim director of the university's Integrated Design Lab and a leader of the Innovative Energy Systems working group at CAES.

Hempitecture is a building materials supplier based in Ketchum, Idaho. HempWool is expected to be created with the fiber from industrial hemp grown sustainably in rural communities across the U.S.

Development of Idaho Sourced Rare Earth Elements project



A collaborative project led by University of Idaho assistant professor **Amin Mirkouei** received a \$348,000 IGEM

award. Mirkouei's project, "Development of Idaho Sourced Rare Earth Elements Drilling and Extraction," involves a team from UI, researchers from Idaho National Laboratory and the Idaho Geological Survey, and industry partner Idaho Strategic Resources.

It calls for research and development on a new technique for drilling and extracting rare earth elements.

"This project capitalizes on the university's research strengths in mining, as well as utilizing key partnerships and expertise around the state," Idaho Commerce Director Tom Kealey said in a news release. "The outcome of this IGEM public-private research project could have a profound economic impact on Idaho's mining industry."

Others involved with the project include:

- Indrajit Charit, professor, UI department chair and CAES resident
- Lee Ostrom, UI, Idaho Falls Center executive officer and professor
- John Russell, UI research professor and CAES associate director for the university
- Claudio Berti, director and state geologist, Idaho Geological Survey
- Virginia Gillerman, economic and mining geologist, Idaho Geological Survey
- Daniel Ginosar, INL
- John Swallow and Robert Morgan, Idaho Strategic Resources



HIGHLIGHTS

Summer Visiting Faculty Program's fifth year

Five faculty members from the CAES universities participated in the fifth annual CAES Summer Visiting Faculty Program. The primary objective of the 12-week program is to support and guide faculty from the CAES universities as they develop a submission-ready research proposal in collaboration with an Idaho National Laboratory researcher who will support their proposal. Members of the cohort participated in professional development, seminars and informational sessions aimed at building the faculty members' understanding of DOE and its core capabilities, INL's strategic initiatives and areas of interest, and best practices in cross-institutional collaboration. The program's long-term objectives include continued partnerships between the faculty member, INL and the CAES consortium; strengthening the consortium's inclusive research community; and supporting science, technology, engineering and math (STEM) research and education across Idaho through collaborative university and laboratory networks.

Here are this year's participants:

- Dahzi Yang, Boise State University, collaborated with Hillary Fishler, CAES, and John Koudelka, Nuclear Science and Technology directorate
- Rajib Mahamud, Idaho State University, collaborated with Ahmed Hamed, Energy and Environment Science and Technology directorate
- Hasan Jamil, University of Idaho, collaborated with Shad Staples, NS&T
- Matthew Swenson, UI, collaborated with Kaustubh Bawane, Materials and Fuels Complex
- Alex Vakanski, UI, collaborated with Fei Xu, MFC, and Yachun Wang, NS&T

CAES Summer Visiting Faculty Program, at a glance:

48 faculty members from the CAES universities have participated since the program's inception in FY-18.

Past projects that have received funding include:

- *An offshoot of a project led by Boise State University's Mike Hurley led to the installation of a 3D metal printer for nuclear-grade materials at CAES.*
- *A project led by Idaho State University's Irene van Woerden and former INL Communications Director Rae Mos called for an in-depth analysis of the public perceptions of nuclear energy.*
- *A project led by Boise State's Edoardo Serra used Lego Mindstorms to help teachers inspire middle-school students pursue careers in cybersecurity.*

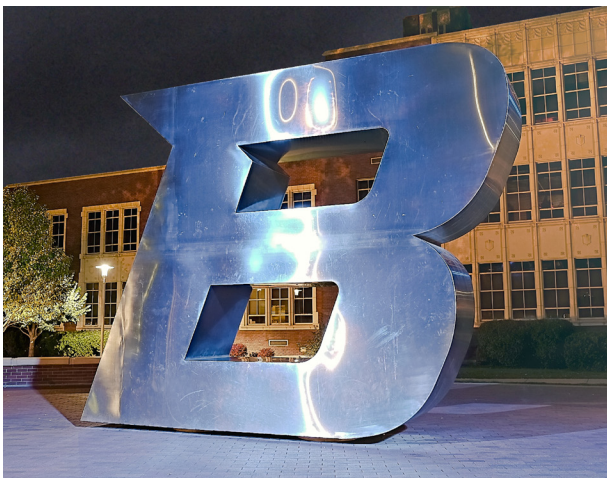
CAES Collaboration Funds celebrates fifth year with record number of submissions

Thirteen projects were selected to receive CAES Collaboration Program Development Funds for 2022, out of a record number of 23 submissions. This marks the fifth year in which these funds have been awarded to projects led by Idaho National Laboratory researchers in partnership with faculty members/researchers from the CAES universities. The goal is to establish and foster relationships between the CAES entities in research, education and innovation. This year, CAES leadership selected 13 proposals best suited to enhance collaborative relationships among the CAES entities.

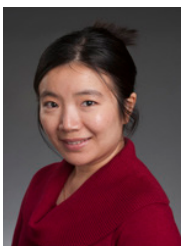
- *This year, the program's fifth year, 13 proposals were awarded out of a record number of submissions (23).*
- *Since the program's inception, 42 projects have been awarded for a total of \$1,018,862 in CAES funding.*
- *Eight white papers produced, new course material developed at each university, several seminars held, one award through INL's Laboratory Directed Research and Development program.*
- *The largest awards to emerge are a \$1.1 million award through the Idaho Global Entrepreneurial Mission for an ISU/INL project and a \$430,000 award from the Office of Nuclear Safety, also for an INL/ISU project.*
- *Since FY-20, 25 graduate students, a Ph.D. student and three interns have supported these projects.*
- *Since the program began, 26 proposals have been submitted, including five pending from FY-22.*

Principal Investigator	INL Researcher(s)	INL Directorate(s)	CAES Focus Area
Boise State University			
Lan Li (with Amir Ali)	Joshua Fishler	NS&T	Nuclear Energy
Brian Jaques	Junhua Jiang	NS&T	Nuclear Energy and Advanced Manufacturing
Sing Ming Loo	Eleanor Taylor	N&HS	Cybersecurity and Innovative Energy Systems
Idaho State University			
Amir Ali (with Lan Li)	Joshua Fishler	NS&T	Nuclear Energy
Mostafa Fouda	Md Riaz Kayser Ahmed Hamed	NS&T EES&T	Nuclear Energy
Mustafa Mashal	Vaibhav Yadav	NS&T	Nuclear Energy
Mustafa Mashal	Kunal Mondal	EES&T	Nuclear Energy
Mustafa Mashal	Xingyue Yang, Rajiv Khadka John Koudelka	NS&T	Computing, Data and Visualization
Anirban Chakraborty	Asef Redwan	EES&T	Energy-Water Nexus
Leslie Kerby	Ryan Stewart	NS&T	Nuclear Energy and Computing, Data and Visualization
University of Idaho			
Min Xian	Mukesh Bachhav	MFC	Advanced Manufacturing
Haiyan Zhao	Hanping Ding	EES&T	Innovative Energy Systems
Ahmed Ibrahim	Elmar Eidelpes Gabriel Ilevbare	NS&T EES&T	Nuclear Energy
Indrajit Charit	Cheng Sun	MFC	Advanced Manufacturing

NS&T= Nuclear Science and Technology, EES&T= Energy & Environment Science & Technology,
N&HS=National & Homeland Security, MFC=Materials & Fuels Complex



Paper on collaborative research effort published



Researchers from Idaho National Laboratory, Boise State University and University of Idaho who are working on a project studying the

long-term performance and safety of lithium-ion batteries had their work published in the journal *Small*. The project, which is funded by INL's Laboratory Directed Research and Development program, focuses on the least understood areas of the batteries, the solid electrolyte interphase (SEI). The SEI is the region at the interface between the battery electrodes and the electrolyte and enables the transport of charge. The research team includes Boise State

professors [Claire Xiong](#) and [Lan Li](#), who are both CAES fellows; UI's I. Frank Cheng; and INL's Eric Dufek. The work utilized nondestructive electrochemical-atomic force microscopy to systematically monitor and compare the dynamic SEI formation and evolution on a pair of representative graphitic materials with and without defects. The outcome is a comprehensive understanding of the formation and evolution of SEI on graphitic electrodes.

"Through this collaboration, we discovered that defects in the graphite structure induce the formation of a thinner, denser and more uniform SEI, which leads to improved battery performance," said Xiong, the principal investigator. "We now have a new design strategy to overcome the Achilles's heel of lithium-ion batteries — limited charge cycling capacity."

Boise State University professor teams with INL on materials science research effort

Boise State University associate professor Paul Simmonds is collaborating with Idaho National Laboratory on research that calls for using a process called molecular beam epitaxy to enable the study of the elements that form the foundation of nuclear energy production. The process will enable Simmonds and his colleagues to "grow" materials with few defects, allowing them to observe the movement of electrons and phonons with unparalleled accuracy. Current studies of the movement of the electrons and phonons found in these elements (uranium, plutonium and other actinides) are limited in part because of defects and impurities. Molecular beam epitaxy will allow the researchers to create a structure with the desired elements arranged in a predetermined arrangement, enabling the electronic and thermal properties of the materials and the observation of quantum mechanical effects. It also could lead to additional research on actinide materials at INL.



ISU awards seed grants for collaborative research efforts

TEN researchers at Idaho State University received \$243,000 in ISU-CAES seed grants in December for collaborative research projects involving partners from Idaho National Laboratory and the other CAES universities. The projects range from microreactor design to pumped hydropower to high performance computing. The funding for the projects comes from the portion of ISU's annual state funding allocated for CAES activities.

1. **Amir Ali**, a Nuclear Engineering Department faculty member, is collaborating with INL researcher Yasir Arafat on a project called *"Performance Optimization of MARVEL Microreactor Power Conversion System"*
2. **Paul Bodily**, a faculty member in the Computer Science Department, is collaborating with INL researcher Rajiv Khadka on *"Application of Advanced Computational Theory to Facilitate Efficient Solutions to Real-World Combinatorial Problems"*
3. **Tony Forest**, a Physics Department faculty member, is collaborating with Chutiing Tan (INL) on *"A Neutron Generator for Materials Testing"*
4. **Mostafa Fouda**, a faculty member in the Electrical and Computer Engineering Department, is collaborating with Ahmed Hamed (INL) on *"Smart Analytics of Biomass Images"*
5. **Jon Kalivas**, a faculty member in the Chemistry Department, is collaborating with John Koudelka (INL) on *"Virtual Reality for Dynamic Data Visualization of Analytical Chemical Data"*
6. **Mustafa Mashal**, a Civil Engineering Department faculty member, is collaborating with fellow ISU researchers Dan LaBrier and Jared Cantrell, and INL researchers Som Duhlipala and Amit Jain on *"Machine Learning-Aided Validation of a Sustainable and Highly Durable Construction Technology for the Containment Facility of Advanced Reactors"*
7. **Srinath Pashikanti**, a faculty member in the Biomedical and Pharmaceutical Sciences Department, is collaborating with fellow ISU researcher Rene Rodriguez and INL researchers Robert Fox and Donna Baek on *"Incorporation of Sterics in Novel Phosphonium Ionic Liquid (PIL) and Their Effect on Ligand Intermolecular Interactions and Chelation Properties"*
8. **Bruce Savage**, a Civil Engineering Department faculty member, is collaborating with fellow ISU researchers Chikashi Sato, Jim Mahar and Mustafa Mashal, and University of Idaho researchers Karen Humes and Dakota Roberson on *"Water Storage Infrastructure Viability Using Repurposed Tires for Pumped Hydro"*
9. **Keith Weber**, Geographic Information Systems Training and Research Center director, is collaborating with Boise State University's Kathleen Araújo and Cassandra Koerner, and INL researchers Kelly Wilson, Ryan Hruska, Shiloh Elliot and Chris Forsgren on *"The Power Grid/Wildfire Nexus: Using GIS and Satellite Remote Sensing to Identify Vulnerabilities"*
10. **Danny Xu**, a faculty member in the Biomedical and Pharmaceutical Sciences Department, is collaborating with Boise State researcher Kenneth Cornell and INL's Eric Whiting on *"Hearing Loss Prevention Through Integrative High-Performance Computing, Data Science and Experimental Biology"*

Collaborative project on wastewater involves INL, Boise State University



A collaborative research effort involving Boise State University, Drexel University and Idaho National Laboratory has demonstrated an energy-efficient,

conceptually simple technique to remove ammonia from agricultural wastewater. The research team — co-led by [David Estrada](#), associate professor of Materials Science and Engineering at Boise State University and the CAES associate director for Boise State, and Tedd Lister, a chemical separations researcher in INL's Energy and Environment Science and Technology directorate — has published an article in the Nature Partner Journal Clean Water on their work. The project demonstrates a technique for removing dissolved ionic impurities from wastewater without the use of filters or high pressure that uses a fraction of the energy of traditional methods. The technique utilized by the research team, capacitive deionization (CDI), is an emerging water treatment technique in which water flows between two oppositely charged electrodes. The ionic impurities in wastewater are polarized, which causes the anions to

be attracted and stored in the positive electrode while the cations are attracted and stored in the negative electrode.

"The neat advantage with CDI is that you can reverse the charges on the electrodes and repel the stored ions into a concentrated stream", said Luis Diaz-Aldana, a member of the research team who is an electrochemical engineer in INL's Energy and Environment Science and Technology directorate. "So not only can you clean water, but you can also recover any precious resources that were discharged into the wastewater."

Previous studies have explored carbon-based materials as electrodes in the CDI system. However, these materials can be limited in chemical diversity, surface chemistries and surface-area-to-

volume ratio, which all combine to limit performance in CDI systems. This prompted the team to partner with Chris Schuck and Yury Gogotsi at Drexel University to investigate the efficacy of MXenes in a flowing electrode CDI system.

Naqsh Mansoor, a Boise State graduate student in materials science and engineering, was first author on the article, which explained that using MXenes in a flow electrode style CDI architecture results in 100 times improvement in the deionization capacity of the system when compared to activated carbon based electrode systems. This essentially means that a higher number of pollutant ions can be pulled out from the wastewater stream while using less of the electrode material and a fraction of the energy.

CAES leadership approves new capabilities for lab

The CAES Executive Board approved the Electronics for Frequency-Domain Feedback Laboratory, expanding the capabilities of the Innovation Laboratory. Led by Idaho National Laboratory's Robert England, the project enables research into instrumentation and controls as well as data science. Idaho State University assistant professor Mostafa Fouda and University of Idaho assistant professor Dakota Roberson are co-principal investigators on the project.



CAES launches seed grant program for MaCS

CAES launched the Microscopy and Characterization Suite (MaCS) Seed Grant Program in the spring to boost opportunities for members of the CAES community to conduct research in the MaCS. The program covers the costs of instrument time and MaCS staff time for selected proposals. The goal is to seed opportunities that advance the vision and mission of CAES, promoting research in all science fields and increasing the MaCS user base.

MaCS is a state-of-the-art materials characterization laboratory with a range of technologically advanced equipment including two scanning transmission electron microscopes and local electrode atom probe that provides cross-cutting capabilities in support of the CAES mission in several areas. MaCS is largely made possible through its partnership with the Nuclear Science User Facilities.

The seed grant program is led by Boise State University and Idaho State University, as well as Boise State's Micron School of Materials Science and Engineering.



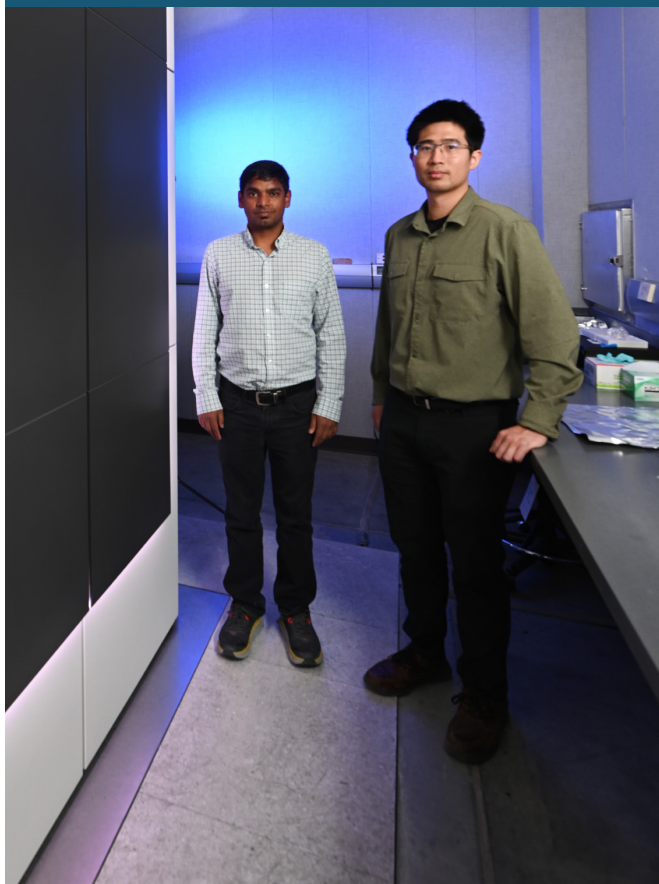
Boise State University, INL collaborate on high-density fuel project

A collaborative project led by Boise State University assistant professor Brian Jaques, Boise State Ph.D. student/Idaho National Laboratory Graduate Fellow [Jennifer Watkins](#), and INL researcher Adrian Wagner is the subject of three recent review articles. The articles provide a review of the challenges and opportunities associated with the use of four types of high-uranium density fuels in existing and future light water reactors — uranium diboride, uranium carbide, uranium silicide and uranium mononitride.

In general, increasing the uranium density of fuels in these reactors can provide many benefits, including increased power-up rates, longer cycle lengths, improved performance and increased coping time during accident scenarios. However, the fuels also exhibit undesirable corrosion behavior. The articles delve into the need for increased study into this behavior, to identify ways to protect the fuel matrix from degradation. The project findings indicate that further research is warranted due to the potential benefits of using high-uranium density fuels, from safety, economical and nonproliferation standpoints.

Watkins is a Ph.D. student in Boise State's Micron School of Materials Science and Engineering and is part of the Advanced Fuel Fabrication and Development group at INL's Materials and Fuels Complex. Wagner is a researcher at MFC. Jaques, a CAES fellow, is an assistant professor in the Micron School of Materials Science and Engineering who holds a joint appointment with INL.

The three are joined on the project, which is funded by INL and Westinghouse, by University of Texas at San Antonio researchers Elizabeth Sooby and Adrian Gonzales.



CAES-funded project studying perceptions of nuclear energy featured in publications



A CAES-funded project examining the perceptions of nuclear energy is the subject of two recent publications.

The project stems from the 2020 CAES Summer Visiting Faculty Program, where Idaho State University's **Irene van Woerden**, an assistant professor



in the Department of Community and Public Health, collaborated with former Idaho National Laboratory Communications Director **Rae Moss** to study the public perception of nuclear energy in Idaho.

The team received \$20,000 through the ISU-CAES seed grant program, which provides funding for collaborative projects involving researchers from the university and INL, to launch a survey. More than 6,000 people responded to at least one question in the survey, with more than 2,000 responses from Idahoans. The target audience lived within 50 miles of the INL Site.

"We had a much wider and larger response rate than expected," van Woerden said.

She and Moss recruited three graduate students pursuing their master's in public health at ISU to help conduct the survey and analyze the responses.

The survey included questions related to:

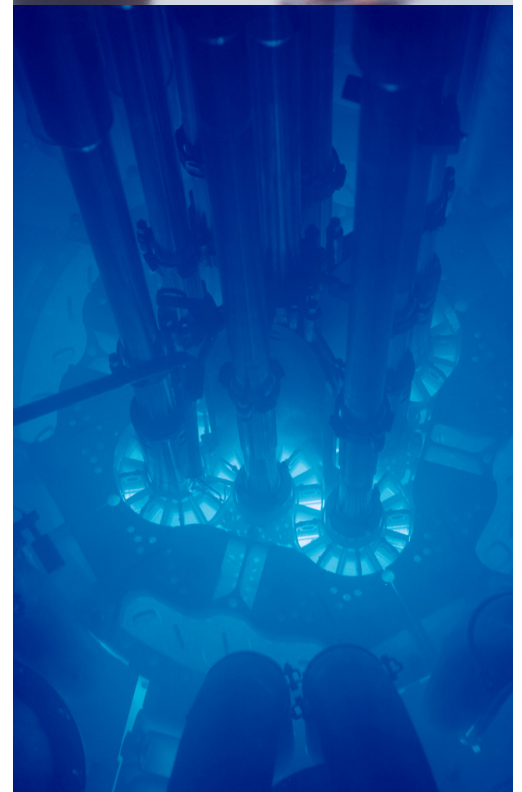
- Demographics
- Attitudes toward nuclear energy
- Perceived risk of nuclear energy
- Environmental factors
- Health concerns related to nuclear energy
- Nuclear waste
- Knowledge of nuclear energy
- Economics of nuclear energy
- Questions on the respondents' health status, food security status, and community and disaster preparedness.

One paper, published in May, was written by van Woerden; Megan Warnement Wrobel, an assistant professor of political science at ISU; and Mark McBeth, a professor of political science at ISU. The article, "Political ideology and nuclear energy: Perception, proximity and trust," was published in May in Review of Policy Research.

The second article, published in April in Energies, was written by ISU graduate student Meesha Iqbal, Moss and van Woerden. It is called, "Peoples' perception toward Nuclear Energy."

The research team is also preparing another article about the perceptions of nuclear energy related to climate change and nuclear waste.

"The general idea behind this work is that the perception toward nuclear energy is a vital factor determining the success or failure of nuclear projects," van Woerden said. "We welcome additional collaboration with those who are interested to use this survey."





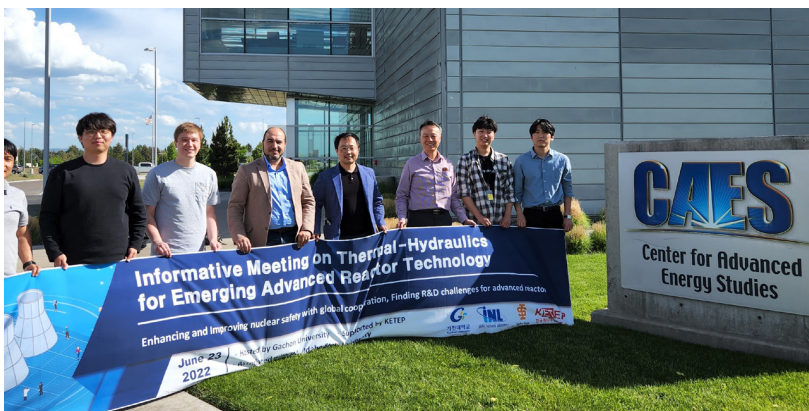
EVENTS **Diverse group turns out for innovation workshop at CAES**

More than 70 people attended a workshop at CAES designed to develop a roadmap for receiving funding through the National Science Foundation's Regional Innovation Engines program. The program catalyzes and fosters innovation ecosystems across the nation, providing up to 10 years of funding, as much as \$160 million, to each "engine" to establish and support diverse regional coalitions that engage in research and development, workforce development and translating innovation to society. A collaborative team from Idaho National Laboratory, Boise State University and CAES submitted a concept paper to NSF over the summer that was accepted, resulting in the workshop. The workshop drew attendees from industry, academia, INL, local government and community organizations, and resulted in the formation of a comprehensive team charged with developing a full phase 1 proposal to submit to NSF that could lead to an innovation "engine" based in eastern Idaho.

Energy Policy Institute hosts annual conference



The Energy Policy Institute at Boise State University held the 10th annual Energy Policy Conference in mid-October 2021. More than 200 people attended, the best draw in the event's history. Keynote speakers included Idaho National Laboratory Director John Wagner; Abigail Ross Hopper, president and CEO of the Solar Energy Industry Association; William Magwood, director-general of the Nuclear Energy Agency; Jennifer Fordham, former senior vice president of Government Affairs for the Natural Gas Supply Association; and Jon Wellingshoff, CEO of Grid Policy, Inc. and former chairman of the Federal Energy Regulatory Commission. The conference featured sessions on resilience in the power sector and the future of electric vehicles, all revolving around the conference's theme of "Disruption and Megatrends in Energy." The conference was cancelled in 2020 due to the COVID-19 pandemic.



Boise State University hosts workshop

More than a dozen researchers, from Boise State University, Idaho National Laboratory and Idaho State University, attended a workshop hosted by Boise State in August. The goal of the event was to formulate a plan to develop an Engineering Research Center proposal. Engineering Research Centers are university-led institutions developed through the National Science Foundation's Directorate of Engineering. The center would be housed at Boise State, would include all of the CAES institutions, and would focus on advanced manufacturing for renewable energy.

CAES hosts meeting with South Korean scholars

CAES hosted a meeting at its facility last spring with a contingent of researchers and faculty members from Gachon University in South Korea. The meeting was part of an effort started by Idaho National Laboratory in 2020 to develop an international research and education force to support the deployment of advanced reactors. Representatives from the two groups discussed implementing an international student and scholar exchange between Idaho State University and Gachon University to encourage collaboration. A memorandum of understanding is being developed to formalize the relationship.

CAES hosts student chapters of American Nuclear Society

CAES hosted an event for the American Nuclear Society student chapters from Boise State University, University of Idaho and Utah State University last spring. The group consisted of 16 students from Boise State, nine from UI and eight from Utah State. Interim CAES Director Terry Brog provided an overview of CAES, and the students toured several laboratories, including the Small Modular Reactor Simulator Laboratory, Microscopy and Characterization Suite and Radiochemistry Laboratory. The event was organized by UI nuclear engineering student Sesily Stewart. The faculty adviser was R.A. Borrelli, an associate professor in nuclear engineering at University of Idaho.

CAES hosts ASME Lunch and Learn

CAES hosted a lunch-and-learn event for the American Society of Mechanical Engineers in August. The event featured a presentation by Bin Li, a senior staff scientist in Idaho National Laboratory's Energy and Environment Science and Technology directorate whose research focuses on energy storage technologies, from discovering new materials to developing novel technologies for lithium-ion and Li-metal batteries.



CAES hosts My Amazing Future

CAES hosted 165 eighth-grade girls and more than two dozen teachers as part of Idaho National Laboratory's annual My Amazing Future in May. The annual event gives the young scholars the chance to explore topics such as DNA extraction from a strawberry, cybersecurity, radioisotope thermoelectric generators, hands-on chemistry and more, at more than a dozen workshops set up across INL's Research and Education campus. They conducted five workshops at CAES.

CAES hosts reception, poster session for REU fellows

Dozens attended a reception at CAES in late July honoring the first cohort of the CAES Research Experience for Undergraduates: Advanced Manufacturing for a Sustainable Energy Future program. The reception featured introductions by Idaho National Laboratory Deputy Director for Science and Technology and Chief Research Officer Marianne Walck and CAES Director Philip Reppert, a poster session and lightning talks on the projects the 10 members of the inaugural cohort worked on throughout the summer.

CAES hosts meeting of regional economic development organization

CAES hosted the quarterly meeting of the Regional Economic Development for Eastern Idaho in June. The group received a briefing from former interim CAES Director Terry Brog and INL Technology Deployment Director Jason Stolworthy on INL's economic impact and the laboratory's role before taking a tour of the CAES facility highlighted by a demonstration in the Applied Visualization Laboratory.

CAES scientist featured in EPI Power Talk webinar



MEETINGS, OPEN HOUSES, SEMINARS AND SPEECHES



Travis McLing, a research scientist with INL and the lead for the Geochemistry Laboratory at CAES, presented at a Power Talk webinar hosted in mid-June by the CAES Energy Policy Institute at Boise State University. More than 150 people tuned in to the event, called “Geothermal Prospects: Federal Policy, Jobs and Technology Build-out.” McLing was joined on the panel by Roy Mink, former director for DOE’s Geothermal Technologies Program; CAES Energy Policy Institute Director Kathy Araújo, who is also an associate professor of Sustainable Energy Systems, Innovation and Policy at Boise State; and Jeff Tester, a professor of Sustainable Energy Systems at Cornell University.

McLing, who serves as INL’s Carbon Storage lead, is an expert in the fields of geologic mapping, carbon sequestration, geomicrobiology and hydrochemistry. He has developed geochemical models to characterize carbon dioxide transport at potential storage sites, and his primary interest in this field is the study of the geochemical mineralization reactions controlling the fate and transport of carbon dioxide in subsurface environments.

Other Power Talk webinars held throughout the year included “EV Infrastructure, Policy, and Fleet Change,” “Economic Opportunities and Challenges for Idaho with Low Carbon Energy Across Sectors” and “Content-Based Siting for Nuclear Energy.”

CAES hosted a number of visitors throughout the year, including:

- Representatives of the Nuclear Regulatory Commission
- Representatives from the National Association of Regulatory Utility Commissioners
- Deputy Assistant Secretary for Nuclear Infrastructure Programs Tracey Bishop
- Representatives of Assistant Secretary for Nuclear Energy Kathryn Huff
- State Rep. Chris Mathias and State Sen. James Ruchti
- Idaho Falls Mayor Rebecca Casper
- Ammon Mayor Sean Coletti
- A contingent from the International Atomic Energy Agency
- Bingham County Commissioners Mark Bair, Jessica Lewis and Whitney Manwaring
- Idaho Falls City Council members Jim Francis and John Radford
- Julie Horman and Josh Sorensen with U.S. Rep. Mike Simpson’s office
- A delegation from several minority-serving institutions
- A contingent from the University of Utah
- Representatives from industry, including Westinghouse, Dominion Energy, Exelon, Sargent & Lundy, Southern Company and Florida Power & Light Company
- A contingent from Western Wyoming Community College
- Members of the Idaho Falls Chamber of Commerce
- A representative from ClearPath’s Advanced Reactor IES Expert Group
- Members of the state’s Leadership in Nuclear Energy (LINE) Commission
- Representatives from the Idaho Public Utilities Commission, Idaho Governor’s Office of Energy and Mineral Resources, and Idaho Department of Environmental Quality
- A group from the Federal Reserve Bank’s Salt Lake City branch
- A delegation from Montana Technological University.



Codebreaker

This monthly webinar provides a forum for students and researchers to address their work, communicate opportunities and challenges to a receptive audience, and increase dialogue among CAES affiliates. Presenters in 2022:

Indrajit Charit

University of Idaho professor Indrajit Charit discussed the role of materials research and development in advancing nuclear energy.

Sarah Freeman

Idaho National Laboratory Industrial Control Systems cybersecurity analyst Sarah Freeman described cyberthreat intelligence and attacker trends that challenge cyber forensics.

SM Shafiul Alam

Idaho National Laboratory's SM Shafiul Alam, a research scientist in the Power and Energy Systems Group in INL's Energy and Environment Science and Technology directorate, discussed a collaborative effort with Idaho Falls Power that called for the use of an energy storage

system in a field demonstration of an islanded distribution grid's black start capabilities.

Damon Woods

Damon Woods, the interim director of University of Idaho's Integrated Design Lab, talked about the research underway at the lab and how the systems we design impact our lives.

Jackson Harter

INL scientist Jackson Harter discussed his research on advanced materials and how he used the Applied Visualization Laboratory at CAES to further it.

Amir Ali

Idaho State University professor Amir Ali, the lead of the Innovation Laboratory at CAES, discussed advanced reactors.

Bryon Marsh and Mustafa Mashal

The Disaster Response Complex at ISU was the focus of a presentation by Bryon Marsh, a manager of business relations and training programs with National and

Homeland Security's Emergency Response and Readiness organization at INL, and ISU assistant professor Mustafa Mashal.

Haiyan Zhao

University of Idaho's Haiyan Zhao discussed her work exploring the use of molten salt in applications such as fuel cells, batteries, heat storage and transfer, pyroprocessing of spent nuclear fuels and reactors.

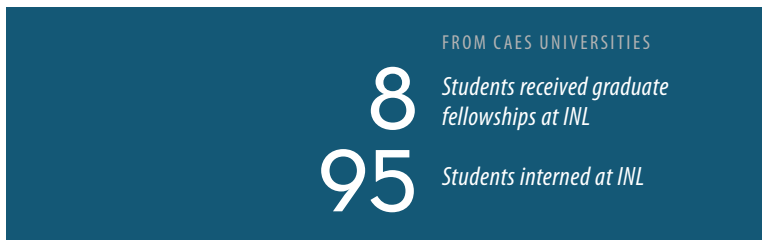
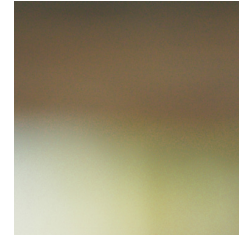
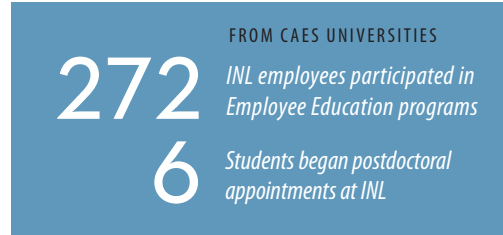
Benny Varghese

INL's Benny Varghese discussed research underway at INL's Electric Vehicle Infrastructure Laboratory.

Yasir Arafat

Yasir Arafat, the technical lead for the Microreactor Applications Research Validation and Evaluation (MARVEL) Project at INL, provided an overview of the project and its potential to pave the way for deployment of a new class of nuclear reactors.

BY THE NUMBERS



Nuclear Science User Facilities-funded projects in MaCS in FY22:

Title	Organization
Dislocation loop and bubble evolution in helium irradiated ThO ₂ and UO ₂ single crystals	The Ohio State University
Irradiation Effects on Unexpected Deformation-Induced Martensitic Phase Transformation in Ni-alloys	Purdue University
Grain Boundary Evolution During Irradiation in RPV Steels	University of Michigan
Irradiation effects on microstructure and mechanical properties in a laser welded ODS alloy	University of Idaho
Ion Irradiation and Characterization of FeCrAl Oxide Dispersion Strengthened Alloy Manufactured via Laser Powder Bed Fusion	Oregon State University
Irradiation behavior of nanostructured ferritic/martensitic Grade 91 steel at high dose	Missouri Science and Technology
Atom probe characterization of oxide and metal/oxide interface on proton irradiated Zry-4 after exposure in high-temperature water	University of Michigan
Accelerated Irradiation and Evaluation of Ultrastrong and Elastic Glassy Carbon	Idaho National Laboratory

PUBLICATIONS AND PROCEEDINGS

Boise State University

Aghajanzadeh, M., F. Zamani, K. Rajabi, J. Eixenberger, D. Shirini, D. Estrada, and F. Shirini. 2022. "Synergic Antitumor Effect of Photodynamic Therapy and Chemotherapy Mediated by Nano Drug Delivery Systems," *Pharmaceutics* 14(2):322. <https://doi.org/10.3390/pharmaceutics14020322>

Ansolabehere, S., K. Araújo, Y. He, A. Hu, V. Karplus, H. Li, E. Thom, and D. Tingley. 2021. "A Low Carbon Energy Transition in Southwest Pennsylvania," Roosevelt Project Report, MIT-Harvard.

Araújo, K. 2022. "Energy Transitions and Nuclear Technology in the Arctic," Arctic X Conference.

Araújo, K. 2022. "Strategic Directions for U.S. Industrial, Climate and Trade Policy," Atlantic Council.

Araújo, K. 2022. "Transitions to Net Zero Carbon Systems: Domestic and International Strategies in Policy and Infrastructure Change," presented at Santa Fe Institute, November 3, 2021.

Araújo, K. 2022. "U.S. Science, Technology and Policy Imperatives for Methane: Applicability for Renewable Natural Gas," presented at AIChE 3rd Renewable Gas Summit, December 14, 2021.

Araújo, K. 2022. "Adoption of Offshore Wind," presented at Advanced Energy Conference 2022: Charting the Course for Energy, New York City, NY. September 2022.

Araújo, K. 2022. "Bending the Energy Curve: Insights for Planning and Community-informed Decision-making," Alaska Center for Energy and Power.

Araújo, K. 2022. "Disruptive Change: Concepts and Lessons for Sustainability," presented at 3rd Latin American Conference on Sustainable Development of Energy, Water and Environment Systems, Sao Paulo, July 2022.

Araújo, K. 2022. "Energy and Demand," presented as panel moderator and on the scientific advisory board, at the Energy and Climate Transformations: 3rd International Conference on Energy Research & Social Science, University of Manchester, UK, June 2022.

Araújo, K. 2022. "Geopolitics, the Net Zero Carbon Agenda, and Technology Change: Interdependencies in Energy," Federal University of Rio de Janeiro.

- Araújo, K. 2022. "The Evolving Field of Energy Transitions," Routledge Handbook of Energy Transitions. Routledge: London, UK and New York, NY.
- Araújo, K. 2023. "A Roadmap for Concepts and Theory of Energy Transitions," Routledge Handbook of Energy Transitions. Routledge: London, UK and New York, NY. <https://doi.org/10.4324/9781003183020>.
- Araújo, K. INL-HP Net Zero Summit.
- Araújo, K., T. Foxon, J. Markard, R. Raven, and R. Schaffer. 2022. "Reconceptualizing the Next Frontier," Routledge Handbook of Energy Transitions. Routledge: London, UK and New York, NY. <https://doi.org/10.4324/9781003183020>.
- Barnes, P., Y. Zuo, K. Dixon, D. Hou, S. Lee, Z. Ma, J. G. Connell, H. Zhou, C. Deng, K. Smith, E. Gabriel, Y. Liu, O. O. Maryon, P. H. Davis, H. Zhu, Y. Du, J. Qi, Z. Zhu, C. Chen, Z. Zhu, Y. Zhou, P. J. Simmonds, A. E. Briggs, D. Schwartz, S. P. Ong, H. Xiong. 2022. "Electrochemically induced amorphous to rock salt phase transformation in niobium oxide electrode for Li-Ion Batteries," *Nature Materials* 21 no. 795-803.
- Bateman, A., C. Snyder, S. Schier, A. Stevanovic, A. Fernandez, E. Sooby, and B. J. Jaques. 2023. "Location specific characterization of additively manufactured stainless steel to inform build data analytics," *The Minerals, Metals & Materials Society* (forthcoming).
- Biaggne, A., L. Spear, G. Barcenas, M. Ketteridge, Y. C. Kim, J. S. Melinger, W. B. Knowlton, B. Yurke, and L. Li. 2022. "Data-Driven and Multiscale Modeling of DNA-Templated Dye Aggregates," *Molecules*, 27 (11): 3456. <https://doi.org/10.3390/molecules27113456>.
- Biaggne, A., Y. C. Kim, J. Melinger, W. B. Knowlton, B. Yurke, and L. Li. 2022. "Cy5 Homodimers and Cy5-Cy5.5 Heterodimers Attached to Holliday Junctions," *RSC Advances* 12: 28063. <https://doi.org/10.1039/d2ra05045e>.
- Black, G. 22nd National Business and Economics Society Conference.
- Black, G., D. Shropshire, K. Araújo, and A. van Heek. 2022. "Prospects for Nuclear Microreactors: A Review of the Technology, Economics and Regulatory Considerations," *Nuclear Technology* 209:sup1, S1-S20. <https://doi.org/10.1080/00295450.2022.2118626>.
- Briggs, A. E., F. Muramutsa, J. D. Wood, C. Husko, J. Logan, S. V. Pedersen, B. J. Jaques, and D. Estrada. 2022. "Isolation of Few-Layer Black Phosphorus for Additive Manufacturing of Optoelectronic Devices," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Anaheim, CA, February 2022.
- Briggs, A. E., F. Muramutsa, J. D. Wood, C. Husko, J. Logan, S. V. Pedersen, B. J. Jaques, and D. Estrada. 2022. "Isolation of Few-Layer Black Phosphorus for Additive Manufacturing of Optoelectronic Devices," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.
- Briggs, A. E., T. Varghese, J. Manzi, H. Subbaraman, and D. Estrada. 2022. "Multiprinter Additive Manufacturing of Flexible Thermoelectric Energy Harvesters Using Colloidal Nanoparticles," presented at The Minerals, Metals, and Materials (TMS) Society Annual Meeting & Exhibition, Anaheim, CA, February 2022.
- Briggs, A. E., T. Varghese, J. Manzi, H. Subbaraman, and D. Estrada. 2022. "Multiprinter Additive Manufacturing of Flexible Thermoelectric Energy Harvesters Using Colloidal Nanoparticles," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.
- Cervantes-Salguero, K., A. Biaggne, J. M. Youngsman, B. M. Ward, Y. C. Kim, L. Li, J. A. Hall, W. B. Knowlton, E. Graugnard, and W. Kuang. 2022. "Strategies for Controlling the Spatial Orientation of Single Molecules Tethered on DNA Origami Templates Physisorbed on Glass Substrates: Intercalation and Stretching," *International Journal of Molecular Sciences*, 23(14): 7690. <https://doi.org/10.3390/ijms23147690>.
- Chen, T., M. Ghayoor, S. Pasebani, Y. Lu, C-H. Shiau, Y. Wu, Y. Li, L. Shao, and R. Prabhakaran. 2022. "Microstructural and Mechanical Responses of Ion-Irradiated 304 Stainless Steel and 304 Oxide-Dispersion-Strengthened Steel Additively Manufactured via Selective Laser Melting," presented at Sixth International Workshop on Structural Materials for Innovative Nuclear Systems (SMINS-6) September 2022.
- Cole, S. E., A. E. Lupercio, A. T. Nelson, and B. J. Jaques. 2022. "Fabrication and Characterization of Doped UO2 Nuclear Fuel," presented at Idaho Conference on Undergraduate Research, Boise, Idaho.
- Curtis, M., C. Chen, J. Redwing, and D. Estrada. 2022. "Fundamentals of MOCVD," presented at 2DCC NSF Site Visit.
- Curtis, M., C. Chen, J. Redwing, and D. Estrada. 2022. "MOCVD Growth of MoS2 and WS2," presented at 33rd Annual Symposium of the Pacific Northwest Chapter of the American Vacuum Society and 41st Symposium on Applied Surface Analysis, Richland, WA. September 2022.
- Davis, P. H. 2022. "Atomic Force Microscopy: Elucidating Material Structure and Properties at the Nanoscale," presented at 33rd Annual Symposium of the Pacific Northwest Chapter of the American Vacuum Society and 41st Symposium on Applied Surface Analysis, Richland, WA. September 2022.
- Deng, Z. 2022. "Additive manufacturing of piezoelectric force sensors," presented at SPIE Smart Structures and NDE 2022.

- Deng, Z. 2022. "Additive Manufacturing of Smart Materials presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.
- Deng, Z. 2022. "All printed flexible and morphing electronics," presented at SPIE Smart Structures and NDE 2022.
- Deng, Z. 2022. "Magnetostrictive Ultrasonic Waveguide Transducer for In-Pile Thermometry," presented at IEEE/ASME Transactions on Mechatronics.
- Deng, Z. 2022. "Simulation of printed surface acoustic wave thermometer," presented at SPIE Smart Structures and NDE 2022.
- Dhakal, S., A. Bateman, B. Panton, J. Bunn, and B. J. Jaques. 2022. "Understanding the Effects of Residual Stress in Mechanical Behavior of SS-316L Manufactured by Laser-wire DED Process," presented at MS&T Materials Science and Technology, Pittsburgh, PA.
- Duncan, K. M., D. L. Kellis, J. S. Huff, M. S. Barclay, J. Lee, D. B. Turner, P. H. Davis, B. Yurke, W. B. Knowlton, and R. D. Pensack. 2022. "Symmetry Breaking Charge Transfer in DNA-Templated Perylene Dimer Aggregates," *Molecules* 27(19): 6612. <https://doi.org/10.3390/molecules27196612>.
- Eixenberger, J., K. Wada, R. Fink, R. Skifton, and D. Estrada. 2022. "Printed High Temperature Irradiation Resistant Thermocouples for Real-time Monitoring of Nuclear Reactor Components," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting.
- Francis, C., Z. Dike, A. Briggs, P. J. Simmonds, J. S. Forbey, and D. Estrada. 2022. "Synthesis and Characterization of Laser-Induced Graphene for Gas Sensing Applications," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Anaheim, CA, February 2022.
- Francis, C., Z. Dike, A. Briggs, P. J. Simmonds, J. S. Forbey, and D. Estrada. 2022. "Synthesis and Characterization of Laser-Induced Graphene for Gas Sensing Applications," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.
- Francis, C., Z. Dike, J. Forbey, and D. Estrada. 2022. "Laser Induced Graphene for Gas Sensing Applications in Environmental Monitoring," presented at Pacific Northwest Chapter of AVS Science & Technology Society, Richland, WA, September 2022.
- Friberg, J., B. Pearson, J. Forbey, D. Estrada, C. Francis, J. Griffin, S. Mark, R. Mark, and A. Nadermann. 2022. "Developing an LIG Sensor," presented at Idaho Conference on Undergraduate Research.
- Fujimoto, K. T, L. A. Hone, K. D. Manning, R. D. Seifert, K. L. Davis, J. N. Milloway, R. S. Skifton, Y. Wu, D. Estrada, and M. Wilding. 2021. "Additive Manufacturing of Miniaturized Peak Temperature Monitors for In-Pile Applications," *Sensors* 21 (22): 7688. <https://doi.org/10.3390/s21227688>.
- Fujimoto, K., M. McMurtrey, T. Unruh, T. Holschuh, L. Hone, P. Moo, and D. Estrada. 2022. "Advanced Manufacturing for the Development of Advanced In-Pile Sensors and Instrumentation," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Anaheim, CA, February 2022.
- Gabriel, E., D. Hou, E. Lee, and H. Xiong. 2022. "Multiphase layered transition metal oxide positive electrodes for sodium ion batteries." *Energy Science & Engineering* 10(5):1672-1705. <https://doi.org/10.1002/ese3.1128>.
- Gupta, S. and L. Li. "The Potential of Machine Learning for Enhancing CO2 Sequestration, Storage, Transportation, and Utilization-based Processes: A Brief Perspective," *The Minerals Metals & Materials Society* 74: 414–428. <https://doi.org/10.1007/s11837-021-05079-x>.
- Hall, S. (with contributors Lenhart, S., Araújo, K., and Vazhnik, V. and reviewers Koerner, C. and Araújo, K.) *Energy, Idaho Climate-Economy Impacts Assessment, Report*.
- Harris, J. D., E. A. Wade, E. G. Ellison, C. C. Pena, S. C. Bryant, N. L. McKibben, A. J. Christy, K. O. Laughlin, A. E. Harris, K. V. Goettsche, C. E. Larson, S. M. Hubbard, J. E. Cowen, J. Eixenberger, D. Estrada, and J. R. Chase. 2022 "Zinc-Acetate-Amine Complexes as Precursors to ZnO and the Effect of the Amine on Nanoparticle Morphology, Size and Photocatalytic Activity," *Catalysts* 12(10): 1099. <https://doi.org/10.3390/catal12101099>.
- Hoffman, A., Z. Yongfeng, A. Maalavan, H. Li, S. Kumar, W. Yaqiao, I. Rinat, V. Ruslan, and W. Haiming. 2023. "Novel Effects of Grain Size and Ion Implantation on Grain Boundary Segregation in Ion Irradiated Austenitic Steel," *Acta Materialia* In Press, available January 23, 2023, no. 118714. <https://doi.org/10.1016/j.actamat.2023.118714>.
- Hou, D., D. Xia, E. Gabriel, J. A. Russell, K. Graff, Y. Ren, C.-J. Sun, F. Lin, Y. Liu, and H. Xiong. 2021. "Spatial and Temporal Analysis of Sodium-Ion Batteries," *ACS Energy Lett.* 6 (11), 4023–4054. <https://doi.org/10.1021/acsenerylett.1c01868>.
- Hou, E., E. Gabriel, K. Graff, T. Li, Y. Ren, Z. Wang, Y. Liu and H. Xiong. 2022. "Thermal Dynamics of P2-Na_{0.67}Ni_{0.33}Mn_{0.67}O₂ cathode materials for sodium ion batteries studied by in situ analysis," *Journal of Materials Research* 37:1156–1163. <https://doi.org/10.1557/s43578-022-00519-z>.
- Hues, J., J. Soares, A. U. Mane, D. Choudhury, S. Letourneau, S. M. Hues, J. W. Elam, and E. Graugnard. 2022. "Thermal

Atomic Layer Etching of MoS₂ Films,” presented at 33rd Annual Symposium of the Pacific Northwest Chapter of the American Vacuum Society and 41st Symposium on Applied Surface Analysis, Richland, WA. September 2022.

- Huff, J. S., S. A. Diaz, M. S. Barclay, A. U. Chowdhury, M. Chiriboga, G. A. Ellis, D. Mathur, L. K. Patten, S. K. Roy, A. Sup, A. Biagne, B. S. Rolczynski, P. D. Cunningham, L. Li, J. Lee, P. H. Davis, B. Yurke, W. B. Knowlton, I. L. Medintz, D. B. Turner, J. S. Melinger, and R. D. Pensack. 2022. “Tunable Electronic Structure via DNA-Templated Heteroaggregates of Two Distinct Cyanine Dyes” *Journal of Physical Chemistry* 126(40): 17164-17175. <https://doi.org/10.1021/acs.jpcc.2c04336>.
- Jiang, J. J. Stempien, Y. Wu. 2023. “Catalyzed Oxidation of Nuclear Graphite by Simulated Fission Products Sr, Eu, and I,” *Journal of Nuclear Materials* 576: 154255. <https://doi.org/10.1016/j.jnucmat.2023.154255>.
- Jiang, J., J. Stempien, L. Shao, and Y. Wu. 2022. “Electrochemical characterization of lightweight glassy carbon irradiated by carbon ion beam,” presented at American Nuclear Society, Nuclear Science user Facilities: I Technical Session, Malibu, HI, June 14, 2022.
- Jiang, J., J. Stempien, and Y. Wu. 2022. “Catalyzed oxidation of nuclear graphite by simulated fission products,” American Nuclear Society, Winter 2022.
- Kempf, N. M., Dubey, Y. Lu, S. Cheng, Y. Wu, and Y. Zhang. “In-Pile Irradiation Effect on Aerosol Jet Printed Silver Sensors,” *Journal of Nuclear Materials*.
- Kempf, N., M. Saeidi-Javash, H. Xu, S. Cheng, M. Dubey, Y. Wu, J. Daw, J. Li and Y. Zhang. 2022. “Thermoelectric power generation in the core of a nuclear reactor,” *Energy Conversion and Management* 268:115949. <https://doi.org/10.1016/j.enconman.2022.115949>.
- Koerner, C. 2022. “Wildfire and electric grid: Crisis requires long-term planning rather than rapid response,” opinion contributor for *The Hill* September 11, 2022. <https://thehill.com/opinion/energy-environment/3594389-wildfire-and-electric-grid-crisis-requires-long-term-planning-rather-than-rapid-response/>.
- Koerner, C., K. Araújo, A. Muth, J. Hampshire, and P. Kharel. “U.S. Wildfire-Power Grid Risk: A Review of Policy and Practices in 10 Western States,”
- Lenhart, S. “Challenges & Opportunities for Power Resilience,” Energy Policy Conference.
- Lenhart, S. “Governance of a Changing Power Grid,” Energy Policy Conference.

Lenhart, S. “Interactive Governance, Structural Power, and Policy Feedback: Regional Transmission Organization Institutional Design and Energy Storage Market Participation,” presented at Energy and Environmental Economics and Policy Seminar Series, Penn State University.

- Lenhart, S. 2022. “Learning and Innovation in a Polycentric Governance Design: Case Study of Electricity System Reliability and Resilience in the Western United States,” presented at Energy and Climate Transformations: 3rd International Conference on Energy Research & Social Science, University of Manchester, UK, June 2022.
- Lenhart, S. 2023. “Lessons from Electric Cooperatives: Evolving Participatory Governance Practices,” *Energy Democracies for Sustainable Futures* 143-150.
- Lenhart, S. and D. Fox. 2021. “Structural Power in Sustainability Transitions: Case Studies of Energy Storage Integration Into Regional Transmission Organization Decision Processes,” *Frontiers in Climate* 3, 1–17. <https://doi.org/10.3389/fclim.2021.749021>.
- Lenhart, S. and D. Fox. 2022. “Participatory democracy in dynamic contexts: A review of regional transmission organization governance in the United States,” *Energy Research & Social Science* 83, no. 102345. <https://doi.org/10.1016/j.erss.2021.102345>.
- Lenhart, S. Western Markets for EUCI Accreditation.
- Liu, K.; Y. Xie, Z. Yang, H-K. Kim, T. L. Dzwiniel, J. Yang, H. Xiong, C. Liao. (2021). “Design of a Single-Ion Conducting Polymer Electrolyte for Sodium-Ion Batteries,” *Journal of the Electrochemical Society* 168 (12), no. 120543. <https://doi.org/10.1149/1945-7111/ac42f2>.
- Lu, Y., Y. Wu, R. Prabhakaran, M. Dubey, L. Shao, J. Wang, and D. Zhang. 2021. “TEM Characterization of High Dose Ion Irradiated MA956 ODS Alloy,” *ANS 2021 Winter* 125(1): 511-513.
- Lu, Y., Y. Wu, R. Prabhakaran, M. Dubey, L. Shao, J. Wang, and D. Zhang. 2022. “Post-Irradiation Examination of High-dose Ion Irradiated MA956 ODS Alloy,” presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.
- Mansoor, N. E., L. A. Diaz Aldana, C. E. Shuck, Y. Gogotsi, T. E. Lister, and D. Estrada. 2022. “Removal and recovery of ammonia from simulated wastewater using Ti₃C₂Tx MXene in Flow electrode capacitive deionization,” *npj Clean Water*. 5: 26. <https://doi.org/10.1038/s41545-022-00164-3>.
- Mansoor, N. E., L. A. Diaz, C. E. Schuck, Y. Gogotsi, T. E. Lister, and D. Estrada. 2022. “Ammonia Removal from Simulated Wastewater Using Ti₃C₂Tx MXenes in Flow Electrode Capacitive Deionization,” presented at 2nd International MXene Conference.

- Mansoor, N. E., L. A. Diaz, C. E. Schuck, Y. Gogotsi, T. E. Lister, and D. Estrada. "Ammonia Removal from Simulated Wastewater Using $\text{Ti}_3\text{C}_2\text{Tx}$ MXenes in Flow Electrode Capacitive Deionization," presented at 242nd Electrochemical Society Meeting, Atlanta, GA.
- Mansoor, N. E., L. A. Diaz, C. E. Shuck, Y. Gogotsi, T. E. Lister, and D. Estrada. 2022. "Removal and recovery of ammonia from simulated wastewater using $\text{Ti}_3\text{C}_2\text{Tx}$ MXene in flow electrode capacitive deionization," *npj Clean Water* 5(26). <https://doi.org/10.1038/s41545-022-00164-3>.
- Manzi, J., A. E. Briggs, T. Varghese, M. Busuladzic-Begic, N. McKibben, D. Estrada, and H. Subbaraman. "Plasma Jet Printing of Colloidal Thermoelectric Nanoflakes for Flexible Energy Harvesting," *Nano Energy*.
- Manzi, J., T. Varghese, J. Eixenberger, D. Estrada, and H. Subbaraman. 2022. "Gravity independent plasma-jet deposition of nanogold for in- space manufacturing of printed flexible electronics," presented at ISS R&D Conference.
- Manzi, J., T. Varghese, J. Eixenberger, D. Estrada, and H. Subbaraman. 2022. "Plasma-jet based printing and in situ sintering of gold patterns for paper-based flexible electronics," presented at FLEX Conference and Exhibition 2022/SEMICON West.
- Mark, S., J. Griffin, R. Mark, J. Ryan, N. Irwin, A. Nadermann, C. Francis, B. Pearson, J. Forbey, D. Estrada, and J. Friberg. 2022. "Bluetooth® Low Energy Sensor Tag for Sagebrush Monitoring," Idaho Conference on Undergraduate Research. <https://scholarworks.boisestate.edu/cgi/viewcontent.cgi?article=2401&context=icur>.
- Maryon, O. O., C. M. Efav, F. W. DelRio, E. Graugnard, M. F. Hurley, and P. H. Davis. 2022. "Co-localizing Kelvin Probe Force Microscopy with Other Microscopies and Spectroscopies: Selected Applications in Corrosion Characterization of Alloys," *Journal of Visualized Experiments* 27(184). <https://doi.org/10.3791/64102>.
- Mass, O. A., C. K. Wilson, G. Barcnas, E. A. Terpetschnig, O. M. Obukhova, O. S. Kolosova, A. L. Tatarets, L. Li, B. Yurke, W. B. Knowlton, R. D. Pensack, and J. Lee. 2022. "Influence of Hydrophobicity on Excitonic Coupling in DNA-Templated Indolenine Squaraine Dye Aggregates," *Journal of Physical Chemistry C*, 126(7): 3475-3488. <https://doi.org/10.1021/acs.jpcc.1c08981>.
- McKibben, N., B. Ryel, A. Draper, D. Estrada, and Z. Deng. 2022. "Additive Manufacturing and Characterization of Surface Acoustic Wave Devices," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Anaheim, CA, February 2022.
- McKibben, N., B. Ryel, A. Draper, D. Estrada, and Z. Deng. 2022. "Additive Manufacturing and Characterization of Surface Acoustic Wave Devices," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Anaheim, CA, February 2022.
- McKibben, N., B. Ryel, J. Daw, D. Estrada, and D. Deng. "Aerosol-jet Printed Surface Acoustic Wave Thermometer," *Additive Manufacturing*.
- McKibben, N., B. Ryel, J. Daw, D. Estrada, and D. Deng. "Aerosol-Jet Printed Surface Acoustic Wave Thermometer," *Microsystems & Nanoengineering*.
- Monpara, G., A. Bateman, Y. Wu, B. Jaques, and R. S. Fertig, III. "Single Crystal Plasticity Framework with Stochastic Strain Bursts for Micron Sized BCC Fe Single Crystal Tensile Test," *Philosophical Magazine*.
- Nguyen, M. Q., B. Jaques, G. Beausoleil, and C-H. Shiau. 2022. "High-Entropy Alloys for Nuclear Application," presented at Idaho Conference on Undergraduate Research.
- Kempf, N., M. Saeidi-Javash, H. Xu, S. Cheng, M. Dubey, Y. Wu, J. Daw, J. Li, and Y. Zhang. 2022. "Thermoelectric power generation in the core of a nuclear reactor," *Energy Conversion and Management* 268:115979. <https://doi.org/10.1016/j.enconman.2022.115949>.
- Novich, K., T. Phero, S. Cole, M. McMurtrey, D. Estrada, B. J. Jaques. 2023. "Additively Manufactured Digital Image Correlation for Nuclear Materials," *The Minerals, Metals & Materials Society* (forthcoming).
- Barnes, P., Y. Zuo, K. Dixon, D. Hou, S. Lee, Z. Ma, J. G. Connell, H. Zhou, C. Deng, K. A. Smith, E. Gabriel, O. O. Maryon, P. H. Davis, H. Zhu, Y. Du, J. Qi, Z. Zhu, C. Chen, Z. Zhu, Y. Zhou, A. E. Weltner, D. Schwartz, P. J. Simmonds, S. P. Ong, and H. Xiong. 2022. "Electrochemically-Induced Amorphous to Rock Salt Phase Transformation in Niobium Oxide Electrodes for Li-Ion Batteries," *Nature Materials* 21: 795-803. <https://doi.org/10.1038/s41563-022-01242-0>.
- Parker, C., O. O. Maryon, M. T. Kaffash, M. B. Jungfleisch, and P. H. Davis. 2022. "Optimizing Magnetic Force Microscopy Resolution and Sensitivity to Visualize Nanoscale Magnetic Domains," *Journal of Visualized Experiments* 20(185). <https://doi.org/10.3791/64180>.
- Patki, P. V., Y. Wu, B. C. Hornbuckle, K. A. Darling, J. P. Wharry. 2022. "Deformation-Assisted Rejuvenation of Irradiation-Induced Phase Instabilities in Cu-Ta Heterophase Nanocomposite," *The Minerals, Metals & Materials Society (TMS)* 74: 4094-4106. <https://doi.org/10.1007/s11837-022-05469-9>.
- Pedersen, S. V, F. Muramutsa, C. Greseth, J. D. Wood, C. Husko, J. Eixenberger, D. Estrada, and B. J. Jaques. 2022. "Mechanochemistry of Phosphorus and Arsenic Alloys for Visible and Infrared Photonics," *Wiley Partner Journal: Advanced Photonics Research* 3(9): 220038,. <https://doi.org/10.1002/adpr.202200038>.

- Pedersen, S. V., F. Muramutsa, J. D. Wood, C. Greseth, C. Husko, J. Eixenberger, D. Estrada, and B. Jaques. 2022. "Mechanochemistry of Phosphorus and Arsenic Alloys for Visible and Infrared Photonics," *Advanced Photonic Research* 3(9): 2200038. <https://doi.org/10.1002/adpr.202200038>.
- Phero, T. L., K. A. Novich, B. C. Johnson, M. D. McMurtrey, D. Estrada, and B. J. Jaques. 2023. "Additively manufactured strain sensors for nuclear applications," *The Minerals, Metals & Materials Society* (forthcoming).
- Phero, T. L., K. A. Novich, B. C. Johnson, M. McMurtrey, D. Estrada, and B. J. Jaques. 2022 "Additively manufactured strain sensors for in-pile applications," *Sensors and Actuators A: Physical* 344: 113691. <https://doi.org/10.1016/j.sna.2022.113691>.
- Rana, S., A. Fleming, N. Kandadai, and H. Subbaraman. 2021. "Active Compensation of Radiation Effects on Optical Fibers for Sensing Applications," *Sensors* 21(24): 8193. <https://doi.org/10.3390/s21248193>.
- Rana, S., H. Subbaraman, A. Fleming, and N. Kandadai. 2021. "Numerical Analysis of Radiation Effects on Fiber Optic Sensors," *Sensors* 21: 4111. <https://doi.org/10.3390/s21124111>.
- Ranganatha, K. L., K. Novich, T. Phero, K. T. Fujimoto, D. Litteken, D. Estrada, B. J. Jaques. and B. C. Johnson. 2021. "A Wireless, Multi-Channel Printed Capacitive Strain Gauge System for Structural Health Monitoring," 2021 IEEE (Institute of Electronic and Electrical Engineers) Sensors, Sydney, Australia, pp. 1-4. <http://doi.org/10.1109/SENSOR547087.2021.9639749>.
- Riley, S., K. Holloway, R. Skifton, and B. J. Jaques. 2022. "High Temperature Irradiation Resistant Thermocouples for In-Pile Temperature Sensing," presented at MS&T Materials Science and Technology, Pittsburgh, PA.
- Riley, S., R. Skifton, and B. J. Jaques. 2022. "Development of drift models for high temperature nuclear thermocouples," *Advanced Sensors and Instrumentation Fall Newsletter*.
- Rui, Y., C. Hsie, S. Pandey, and L. Li. "Applications and Mechanisms of Anisotropic ALE Si₃N₄ Etching with Hydrogen Plasma Conditioning," *Journal of Vacuum Science and Technology*.
- Seva, S., T. L. Phero, A. Olivas, J. Manzi, T. Gabel, T. Varghese, T. R. Dabrowski, J. D. Williams, D. Estrada, and H. Subbaraman. "Multi-Modal Printed Interconnects for Flexible Hybrid Electronic Applications," *IOP Flexible Electronics*.
- Shao, L. and R. Prabhakaran. 2022. "Microstructural and Mechanical Responses of Ion-Irradiated 304 Stainless Steel and 304 Oxide-Dispersion-Strengthened Steel Additively Manufactured via Selective Laser Melting," presented at Sixth International Workshop on Structural Materials for Innovative Nuclear Systems (SMINS-6) September 2022.
- Sikorski, E. L., R. S. Skifton, and L. Li. 2022. "Combined Experimental and Computational Study of Molybdenum and Niobium for Nuclear Sensor Application," *The Journal of The Minerals, Metals & Materials Society (TMS)* 74: 2676-2685. <https://doi.org/10.1007/s11837-022-05317-w>.
- Soares, J., S. Letourneau, M. Lawson, A. U. Mane, Y. Lu, S. M. Hues, L. Li, J. W. Elam, and E. Graugnard. 2022. "Nucleation and growth of molybdenum disulfide grown by thermal atomic layer deposition on metal oxides," *Journal of Vacuum Science and Technology A* 40(6): 062202. <https://doi.org/10.1116/6.0002024>.
- Soares, J., W. Jen, S. M. Hues, and E. Graugnard. 2022. "Intrinsic Area Selective Atomic Layer Deposition of MoS₂ Thin Films," presented at 33rd Annual Symposium of the Pacific Northwest Chapter of the American Vacuum Society and 41st Symposium on Applied Surface Analysis, Richland, WA. September 2022.
- Varghese, T., A. E. Briggs, F. Rajabi-Kouchi, J. Manzi, H. Subbaraman, and D. Estrada. 2022. "Additive Manufacturing of Interface Engineered Colloidal 2D- Crystals for Flexible Thermoelectric Energy Harvesting," presented at Materials Research Society Electronic Materials Conference.
- Varghese, T., A. E. Briggs, J. Manzi, C. Hollar, J. Koehne, J. Jones, C. Hill, H. Subbaraman, and D. Estrada. 2022. "Additive Manufacturing and Interface Engineering of Colloidal Nanocrystals for Flexible Thermoelectric Generators," presented at National Space and Missile Materials Symposium and Commercial and Government Responsive Access to Space Technology Exchange.
- Varghese, T., J. Eixenberger, J. Manzi, H. Subbaraman, and D. Estrada. 2022. "Multi-Jet Compatible Low Temperature Sintering Gold Nano Inks for Epidermal Electronics," presented at FLEX Conference & Exhibition 2022/SEMICON West.
- Wada, K., A. Fleming, and D. Estrada. 2023. "Novel Thermal Conductivity Measurement Technique Utilizing a Transient Multilayer Analytical Model of a Line Heat Source Probe for Extreme Environments," *The Journal of The Minerals, Metals & Materials Society Annual Meeting (accepted)*.
- Wang, F., X. Yan, T. Wang, Y. Wu, L. Shao, M. Nastasi, Y. Lu, and B. Cui. 2021. "Irradiation damage in high-entropy carbide ceramics," presented at MS&T21 Materials Science and Technology, October 2021.
- Wharry, J. P., C. D. Clement, Y. Zhao, S. S. Panuganti, Y. Lu, Y. Q. Wu, D. P. Guillen, and D. W. Gandy. 2022. "Progress in Understanding Irradiation Effects in PM-HIP Nuclear Structural Alloys," presented at MS&T22 materials Science & Technology, October 2022.



Wharry, J. P., P. V. Patki, D. Aksoy, T. J. Rupert, W.-Y. Chen, Y. Wu, and K. A. Darling. 2022. "Immiscible Phase Interfaces: Controlling Irradiation Amorphization and Void Swelling," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.

Wharry, J., C. Yang, T. Olsen, H. Xiong, K. Smith, Y. Wang, K. Hattar, Y. Wu, and D. Tenne. 2021. "Irradiation-enhanced electrochemical performance of TiO₂ anode material," presented at MS&T21 Materials Science and Technology, October 2021.

Wright, N. D., J. S. Huff, M. S. Barclay, C. K. Wilson, G. Barcenas, K. M. Duncan, M. Ketteridge, O. M. Obukhova, A. I. Krivoshey, A. L. Tatarets, E. A. Terpetschnig, J. C. Dean, W. B. Knowlton, B. Yurke, L. Li, O. A. Mass, P. H. Davis, J. Lee, D. B. Turner, and R. D. Pensack. 2023. "Intramolecular Charge Transfer and Ultrafast Nonradiative Decay in DNA-Tethered Asymmetric Nitro- and Dimethylamino-Substituted Squaraines," *The Journal of Physical Chemistry*. <https://doi.org/10.1021/acs.jpca.2c06442>.

Wu, Y. 2021. "Characterization of Nanosized Oxides in Nuclear Materials," presented at Nano-2021-III: 4th edition of Webinar on Nanotechnology, November 8, 2021.

Xiong, C. 2021 "Role of Lithium Doping in Layered Transition Metal Oxide Electrodes for Sodium Ion Batteries," presented at ECS Fall Meeting 2021.

Xiong, C. 27th AACGE Western Section Conference on Crystal Growth & Epitaxy.

Xiong, H., C. Yang, T. Olsen, M.-L. Lau, K. Smith, J. Wharry, K. Hattar, Y. Wang, W.-Y. Chen, Y. Wu, B. Narayanan, M. Long, and D. Hou. 2022. "In situ irradiation of TiO₂ nanotubes," presented at MS&T22 Materials Science & Technology, October 2022.

Yang, C., T. Olsen, M. L. Lau, K. A. Smith, K. Hattar, A. Sen, W. Yaqiao, B. Narayanan, D. Hou, M. Long, J. P. Wharry, and H. Xiong. 2022. "In situ irradiation of anatase and amorphous TiO₂ nanotubes," *Journal of Materials Research* 37: 1144-1155. <https://doi.org/10.1557/s43578-022-00516-2>.

Zhao, Y., S. S. Panuganti, C. Clement, S. Wang, S. Cheng, Y. Lu, Y. Wu, K. Wheeler, D. Guillen, D. Gandy, and J. Wharry. 2022. "Neutron irradiation effects on a powder metallurgical processed SA508 pressure vessel steel," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.

Zhu, H., J. A. Russell, Z. Fang, P. Barnes, L. Li, C. M. Efav, A. Muenzer, J. May, K. Hamal, I. F. Cheng, P. H. Davis, E. Dufekd, H. Xiong. 2021. "A Comparison of Solid Electrolyte Interphase Formation and Evolution on Highly Oriented Pyrolytic and Disordered Graphite Negative Electrodes in Lithium-Ion Batteries." *Small*, 17(52): 2105292. <https://doi.org/10.1002/sml.202105292>.

Idaho State University

- Abdalzاهر, M. S., M. M. Fouda, and M. I. Ibrahim. 2022. "Data Privacy Preservation and Security in Smart Metering Systems," *MDPI Energies* 15(19): 7419. <https://doi.org/10.3390/en15197419>.
- Abdelfattah, S., M. Baza, M. M. E. A. Mahmoud, M. M. Fouda, K. A. Abualsaud, and M. Guizani. 2021. "Multidata-Owner Searchable Encryption Scheme Over Medical Cloud Data With Efficient Access Control," *IEEE Systems Journal* 16(3):5067-5078. <https://doi.org/10.1109/JSYST.2021.3123956>.
- Acharya M. and M. Mashal. 2022. "Structural Concrete Insulated Panels - A Resilient and Affordable Construction Technology," presented at American Public Works Association – 2022 Rocky Mountain Chapter Conference, Pocatello, ID.
- Acharya, M., R. Khadka, M. Mashal. 2022. "Preliminary Bond Testing and Splicing of Titanium Alloy Bars," *Transportation Research Record: Journal of the Transportation Research Board* 2676(5): 410-427. <https://doi.org/10.1177/03611981211067785>.
- Aispuro B. S. and M. Mashal. "Recycled Concrete Aggregate in Eco Friendly Construction," National Diversity in STEM Conference, Society for Advancement of Chicanos/Hispanics & Native Americans in Science (SACNAS), San Juan, Puerto Rico.
- Ali, A., 2021. DOE-NEUP Final Report (lead by the University of Wisconsin), "Critical Heat Flux Studies for Innovative Accident Tolerant Fuel Cladding Surfaces," DE-NE0008681.
- Badr, M. M., M. I. Ibrahim, M. Mahmoud, M. M. Fouda, F. Alsolami, and Waleed Alasmary. 2022. "Detection of False-Reading Attacks in Smart Grid Net-Metering System," *IEEE Internet of Things Journal* 9(2): pp. 1386–1401. <https://doi.org/10.1109/JIOT.2021.3087580>.
- Badr, M. M., M. I. Ibrahim, M. Mahmoud, W. Alasmary, M. M. Fouda, K. H. Almotairi, and Z. M. Fadlullah. 2022. "Privacy-Preserving Federated-Learning-Based Net-Energy Forecasting," SoutheastCon 2022, Mobile, AL. pp. 133-139. <https://doi.org/10.1109/SoutheastCon48659.2022.9764093>.
- Bess, J. D., A. S. Chipman, C. L. Pope, C. B. Jensen, T. Ozawa, S. Hirooka, and M. Kato. 2023. "EBR-II MOX Fuel Characterization Enabling ARES Phase I Testing," *Nuclear Science and Engineering*. <https://doi.org/10.1080/00295639.2022.2156240>.
- Bodily, P. and K. Marchetti. 2022. "KAMI: Leveraging the power of crowd-sourcing to solve complex, real-world problems," *Intermountain Engineering, Technology, and Computing*. <https://doi.org/10.1109/IETC54973.2022.9796945>.
- Bodily, P. and D. Ventura. 2022. "Open Computational Creativity Problems in Computational Theory," presented at International Conference on Computational Creativity.
- Bodily, P. and K. Marchetti. 2022. "Visualizing the 3SAT to CLIQUE Reduction Process," *Intermountain Engineering, Technology, and Computing*. <https://doi.org/10.1109/IETC54973.2022.9796851>.
- Dunker, J. 2022. "RDD Training Utilizing VR and Live Training," presented at 6th Annual International Conference of the Campus Alliance for Advanced Visualization.
- Dunker, J., M. Mashal, and B. Marsh. 2022. "Radiation Dispersal Device Response Training," presented at Disaster Preparedness and Response Conference, Idaho State University, Pocatello, ID.
- Free, Z., M. Hernandez, M. Mashal, and K. Mondal. 2021. "A Review on Advanced Manufacturing for Hydrogen Storage Applications," *Special Issue Materials and Advanced Manufacturing for Sustainable Energy Applications, mdpi Energies*, 14(24): 8513. https://www.mdpi.com/journal/energies/special_issues/SEA.
- Hashesh, A. O., S. Hashima, R. M. Zaki, M. M. Fouda, K. Hatano, and A. S. Tag Eldien. 2022. "AI-Enabled UAV Communications: Challenges and Future Directions," *IEEE Access* 10: 92048-92066. <https://doi.org/10.1109/ACCESS.2022.3202956>.
- Hasnaeen, N. and A. Chrysler. 2021. "Detection of Malware in UHF RFID User Memory Bank using Random Forests Classifier on Signal Strength Data in the Frequency Domain," presented at 2021 IEEE International Conference on RFID.
- He, M., A. Ali, and M. Chen. 2022. "Experimental investigations of Critical Heat Flux re-occurrence on post-CHF surfaces," *Progress in Nuclear Energy* 148: 104211. <https://doi.org/10.1016/j.pnucene.2022.104211>.
- He, M., A. Ali, and M. Chen. 2022. "Steady-State Pool Boiling Heat Transfer Experimental Studies of Horizontally-Placed Tubes," *International Journal of Heat and Mass Transfer* 196: 123270. <https://doi.org/10.1016/j.ijheatmasstransfer.2022.123270>.
- Hegazy, H. I., A. S. Tag Eldien, M. M. Tantawy, M. M. Fouda, and H. A. TagEldien. 2022. "Real-Time Locational Detection of Stealthy False Data Injection Attack in Smart Grid: Using Multivariate-Based Multi-Label Classification Approach," *Energies Special Issue Secure and Efficient Communication in Smart Grids* 15(14): 5312. <https://doi.org/10.3390/en15145312>.
- Hogarth, K., M. Mashal, and J. Cantrell. 2022. "A Disaster Response Complex (DRC) for Research, Curriculum, and Training of First Responders," presented at Disaster Preparedness and Response Conference, Idaho State University, Pocatello, ID.

- Iqbal, M., M. Mashal, M. A. Khan, J. Grider, R. Squires, R. Richardson, J. A. Koudelka, A. Thornley, and I. van Woerden. 2022. "Should we offer disaster preparedness and response training workshops across Idaho? A feasibility study," *Journal of Emergency Management* 20(4): 351-364. <https://doi.org/10.5055/jem.0702>.
- Khadka, R., M. Acharya, D. LaBrier, and M. Mashal. "Visualization of Macroscopic Structure of Ultra-high Performance Concrete Based on X-ray Computed Tomography Using Immersive Environments," In: Chen, J.Y.C., Fragomeni, G. (eds) *Virtual, Augmented and Mixed Reality: Design and Development*. HCII 2022. Lecture Notes in Computer Science, vol 13317. Springer, Cham. https://doi.org/10.1007/978-3-031-05939-1_2.
- Khanal, S, U. S. Medasetti, M. Mashal, B. Savage, R. Khadka. 2022. "Virtual and Augmented Reality in the Disaster Management Technology: A Literature Review of the Past 11 years." *Frontiers in Virtual Reality* 3. <https://doi.org/10.3389/frvir.2022.843195>.
- Ma, Z., S. Zhang, C. Pope, and C. Smith. 2022. "Research to Develop Flood Barrier Testing Strategies for Nuclear Power Plants," NUREG/CR-7279, INL-EXT-19-56427, Idaho National Laboratory, Idaho Falls, ID. <https://www.nrc.gov/docs/ML2205/ML22053A021.pdf>.
- Mashal, M. 2022 Idaho State University Graduate Research Symposium.
- Mashal, M. and S. Dhulipala. 2022. "Machine Learning-Aided Tools to Reduce INL's Concrete Emissions Using Recycled Products," presented at Battelle's Innovations in Climate Resilience, Columbus, OH.
- Mateen, S. K.; R. Rodriguez, D. L. Baek, R. V. Fox, S. Pashikanti. 2022. "Synthesis and Characterization of rigid tetra-alkyl phosphonium based task specific ionic liquids (TSILs)," American Chemical Society, Spring symposium 2022.
- McBride, S. 2022. "Developing the Next Industrial Cyber Workforce," presented at OT Cybersecurity Virtual Summit.
- Medasetti, U. S. 2021. "Virtual Reality and Augmented Reality as Novel Tools for Training of Emergency Responders," 6th Annual International Conference of the Campus Alliance for Advanced Visualization, Idaho State University, Pocatello, ID.
- Medasetti, U. S., A. Sebastian, and M. Mashal. 2022. "Scaled Source Recovery in Mobile Hot Cell Using UR5e," presented at Disaster Preparedness and Response Conference, Idaho State University, Pocatello, ID.
- Medasetti, U. S., J. Dunker, Z. Free, S. Banda, and M. Mashal. 2022. "Disaster Response in VR," presented at Disaster Preparedness and Response Conference. https://boardofed.idaho.gov/wp-content/uploads/2022/08/Final-Report_IGEM20-001_Mashal-Savage_2022.pdf
- Mena, P., R. Borrelli, and L. Kerby. 2022. "Expanded Analysis of Machine Learning Models for Nuclear Transient Identification Using TPOT," *Nuclear Engineering and Design* 390: 111694. <https://doi.org/10.1016/j.nucengdes.2022.111694>.
- Mena, P., R. A. Borrelli, and L. Kerby. 2021. "Survey of Markets for Nuclear Power in Western North America," *International Journal of Energy, Environment, and Economics* 29(1): 17-53.
- Miller, J., S. Ercanbrack, and C. L. Pope. 2022. "The Versatile Economic Risk Tool," *Nuclear Technology*. <https://doi.org/10.1080/00295450.2022.2129273>
- Nasser, N., Z. M. Fadlullah, M. M. Fouda, A. Ali, and M. Imran. "A lightweight federated learning based privacy preserving B5G pandemic response network using unmanned aerial vehicles: A proof-of-concept," *Computer Networks* 205: 108672. <https://doi.org/10.1016/j.comnet.2021.108672>
- Pak, J. J., C. Jenkins, S. Stolworthy, K. P. Olson, C. Osterhout, C. Sudweeks, and R. Hunter. 2022. "CHED: Synthesis of polyurethane model compounds for degradation studies," 263rd ACS National Meeting.
- Peck, J., S. Jenks, M. Mashal, K. Mondal, and B. Savage. 2022. "Advanced Manufacturing for Bulk Storage of Hydrogen," presented at Idaho Conference on Undergraduate Research.
- Pope, C. L. 2022. "Nuclear Reactors – Spacecraft Propulsion, Research Reactors, and Reactor Analysis Topics," September. IntechOpen. <https://doi.org/10.5772/intechopen.95676>.
- Pope, C. L. and W. Phoenix. 2022. "Idaho State University AGN-201 Low Power Teaching Reactor: An Overlooked Gem," <https://dx.doi.org/10.5772/intechopen.105799>.
- Pope, C. L., R. Stewart, and E. Lum. 2022. "Experimental Breeder Reactor II," <https://dx.doi.org/10.5772/intechopen.105800>.
- Rodriguez, R. G., D. L. Baek, M. E. Case, R. V. Fox. 2022. "Studies toward the Use of Ionic Liquids and Supercritical CO₂ for the Recovery and Separation of Praseodymium from Waste Streams," *Catalysts* 12(3): 335, <https://doi.org/10.3390/catal12030335>.
- Rodriguez, R. G.; D. L. Baek, K. Orme, M. E. Case, and R. V. Fox. 2022. "Electrochemical, thermodynamic, and physical properties of tetradecyltrihexylphosphonium ([P₆,6,6,14]⁺) and methyl-propyl piperidinium containing ionic liquids and their propylene carbonate solutions," *Journal of Molecular Liquids* 352: 118607. <https://doi.org/10.1016/j.molliq.2022.118607>.



- Rodriguez, R., D. Baek, M. Case, R. Fox. 2022. "Studies toward the Use of Ionic Liquids and Supercritical CO₂ for the Recovery and Separation of Praseodymium from Waste Streams." *Catalysts* 12, (3) no. 335. <https://doi.org/10.3390/catal12030335>.
- Said, A., S. Hashima, M. M. Fouda, and M. H. Saad. 2022. "Deep Learning-Based Fault Classification and Location for Underground Power Cable of Nuclear Facilities," *IEEE Access* 10: 70126-70142. <https://doi.org/10.1109/ACCESS.2022.3187026>.
- Starks, B., K. Robinson, B. Sitaula, A. M. Chrysler. 2021. "Physical Layer Wireless Security Through the Rotation of Polarized Antennas," presented at 2021 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (APS/URSI), Singapore, Singapore pp. 1483-1484. <https://doi.org/10.1109/APS/URSI47566.2021.9703801>.
- Sudweeks, C. L., R. A. Hunter, S. Stolworthy, K. P. Olson, C. Osterhaut, J. J. Pak, C. Jenkins. 2022. "Irradiation and degradation study of polyurethane model compounds: Abstracts of Papers," presented at ACS Spring National Meeting & Events, San Diego, CA, March 2022.
- Wahlquist, S., A. Ali, S. Yoon, and P. Sabharwall. 2022. "Laminar Flow Heat Transfer in Helical Oval-Twisted Tube Heat Exchanger," *Frontiers in Heat and Mass Transfer* 18. <http://dx.doi.org/10.5098/hmt.18.35>.
- Wahlquist, S., J. Hansel, P. Sabharwall, and A. Ali. 2022. "A Critical Review of Heat Pipe Experiments in Nuclear Energy Applications." *Nuclear Science and Engineering Special issue on Advanced Reactor Thermal Hydraulics Experiments and Modeling Supporting Verification and Validation Needs*. <https://doi.org/10.1080/00295639.2022.2082230>.
- Wells, A., E. D. Ryan, and C. L. Pope. 2022. "Improving Nuclear Power Plant Flooding Hazard Analysis Through Component Performance Experiment, Fragility Model Development, and Smoothed Particle Hydrodynamic Simulation," Elsevier.
- Yadav, V., A. Wells, C. L. Pope, J. P. Andrus, C. P. Chawasz, C. T. Trask, D. E. Eskins, J. Carlson, C. Ulmer, N. Chandran, and R. Lyengar. 2022. "Regulatory Considerations for Nuclear Energy Applications of Digital Twin Technologies," TLR-RES/DE/REB-2022-06, Nuclear Regulatory Commission, Letter Report. <https://www.nrc.gov/docs/ML2219/ML22192A046.pdf>.
- Yockey, W., A. Ali, and C. Pope. "Development of a new control rod drive mechanism design for the ISU AGN-201M reactor," *Annals of Nuclear Energy* 167: 108817. <https://doi.org/10.1016/j.anucene.2021.108817>.

University of Idaho

- Abdullah, A. and F. T. Sheldon. 2022. "A Survey of Crypto-Ransomware Attack Detection Methodologies: An evolving outlook," *Sensors Special Issue: Security and Trustworthiness in Industrial IoT* 22(5): 1837. <https://doi.org/10.3390/s22051837>.
- Adisa, S. B. and M. J. Swenson. 2022. "Temperature Shift for Nanocluster Evolution in Ion-Irradiated Ferritic-Martensitic Alloys," *Journal of Materials* 74: 4069-4080. <https://doi.org/10.1007/s11837-022-05443-5>.
- Albor, G., A. Mirkouei, and E. Struhs. 2022. "Mixed Plastic Waste Conversion to Value-Added Products: Sustainability Assessment and a Case Study in Idaho," ASME IDETC/CIE: 27th Design for Manufacturing and the Life Cycle Conference. <https://doi.org/10.1115/DETC2022-89199>.
- Albulayhi, K., A. A. Smadi, F. T. Sheldon, R. K. Abercrombie. 2021. "IoT Intrusion Detection Taxonomy, Reference Architecture and Analyses." *Sensors*, 21(19): 6432. <https://doi.org/10.3390/s21196432>.
- Albulayhi, K., A. Al-Haija, Q. Smadi, A. Abdullah, and F. T. Sheldon. 2022. "A Comparative Study of IoT Intrusion Detection Using Different Feature Selection Schemes," *Sensors Special Issue Security, Privacy, and Trust Management in IoT*, MDPI.

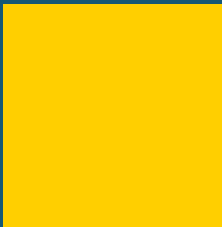


- Albulayhi, K., and F. T. Sheldon. 2021. "An Adaptive Deep-Ensemble Anomaly-Based Intrusion Detection System for the Internet of Things," *IEEE Proc. World AI IoT (AI/IOT) Congress*, Seattle, WA. Pp. 0187-0196. <https://doi.org/10.1109/AllIoT52608.2021.9454168>.
- Albulayhi, K., Q. A. Al-Haija, S. A. Alsuhbany, A. A. Jillepalli, M. Ashrafuzzaman, and F. T. Sheldon. 2022. "IoT Intrusion Detection Using Machine Learning with Hybrid Feature Selection Approach," *Applied Sciences*. <https://doi.org/10.3390/app12105015>.
- Aleisa, M. A., A. Abuhussein, F. S. Alsubaei, and F. T. Sheldon. 2022. "Novel SecurityAleisa, M., A. Abuhussein, F. S. Alsubaei, F. T. Sheldon. 2021. "Examining Performance in Fog-Aided, Cloud-Centered IoT in a Real-World Environment," *Sensors* 21(21): 6950. <https://doi.org/10.3390/s21216950>.
- Almalki, S. A., A. Abdel-Rahim, and F. T. Sheldon. 2022. "Disrupting the Cooperative Nature of Intelligent Transportation Systems," *IEEE World AI IoT Congress (AllIoT)*, Seattle, WA, USA, 2022, pp. 131-137. <https://doi.org/10.1109/AllIoT54504.2022.9817238>.
- Almalki, S. A., A. Abdel-Rahim, and F. T. Sheldon. 2022. "Adaptive IDS for Cooperative Intelligent Transportation Systems Using Deep Belief Networks," *Algorithms Special Issue: AI for Cybersecurity: Robust models for Authentication, Threat, and Anomaly Detection* 15(17): 251. <https://doi.org/10.3390/a15070251>
- AlQahtani, O. and F. T. Sheldon. 2021. "Enhancing Vehicle Ad Hoc Network (VANET) Protocols," *European Wireless 2021; 26th European Wireless Conference*, Verona, Italy, 2021, pp. 1-7.
- AlQahtani, O. and F. T. Sheldon. 2022. "VANET Cluster Merging Weight Factors Study," *IEEE CITS 2022: International Conference on Computer, Information and Telecommunication Systems*, Athens, Greece.
- Brubaker, N., H. Ali, S. Dhakal, N. van Rooyen, M. L. Jaster, I. Charit, B. Jaques, and M. R. Maughan. 2022. "Investigating Microstructure and Properties of 316L Stainless Steel Produced by Wire-Fed Laser Metal Deposition," *Journal of Materials Engineering and Performance* 31: 3508-3519. <https://doi.org/10.1007/s11665-021-06477-7>.
- Butte, S., A. Vakanski, K. Duellman, H. Wang, and A. Mirkouei. 2021. "Potato crop stress identification in aerial images using deep learning-based object detection," *Agronomy Journal* 113(5): 3991-4002. <https://doi.org/10.1002/agj2.20841>.
- Butte, S., H. Wang, M. Xian, and A. Vakanski, 2021. "Sharp-GAN: Sharpness Loss Regularized GAN for Histopathology Image Synthesis," in *Proceedings of the International Symposium on Biomedical Imaging* arXiv:2110.14709v1. <https://doi.org/10.48550/arXiv.2110.14709>
- Cai, L., F. Xu, F. G. Di Lemma, J. J. Giglio, M. T. Benson, D. J. Murray, C. A. Adkins, J. J. Kane, M. Xian, L. Capriotti, and T. Yao. 2022. "Understanding fission gas bubble distribution, lanthanide transportation, and thermal conductivity degradation in neutron-irradiated α -U using machine learning," *Materials Characterization* 184: 111657. <https://doi.org/10.1016/j.matchar.2021.111657>.
- Chatzoglou, E, G. Kambourakis, and C. Kolias. "WiFo: All your passphrase are belong to us." *Computer* 54(7): 82-88. <https://doi.ieeecomputersociety.org/10.1109/MC.2021.3074262>.
- Chatzoglou, E., G. Kambourakis, and C. Kolias. 2022. "How is your Wi-Fi connection today? DoS attacks on WPA3-SAE," *Journal of Information Security and Applications* 64: 103058. <https://doi.org/10.1016/j.jisa.2021.103058>.
- Chatzoglou, E., G. Kambourakis, and C. Kolias. 2022. "Pick quality over quantity: Expert feature selection and data pre-processing for 802.11 Intrusion Detection Systems," *IEEE Access*. <https://doi.org/10.1109/ACCESS.2022.3183597>.
- Chatzoglou, E., G. Kambourakis, and C. Kolias. 2022. "Your WAP Is at Risk: A Vulnerability Analysis on Wireless Access Point Web-Based Management Interfaces," *Security and Communication Networks*.<https://doi.org/10.1155/2022/1833062>.
- Das, S., D. Venugopal, S. Shiva, and F. T. Sheldon. 2022. "Trusting Classifiers with Interpretable Machine Learning Based Feature Selection Backpropagation," *IEEE Transactions on Network and Service Mgmt. (SI: Machine Learning and Artificial Intelligence)*.
- Downey, C., L. Nunez, I. van Rooyen, I. Charit, M. Maughan, and E. Herderick. 2022. "In-situ Powder-directed Energy Process Control for Additively Manufactured Multi-layer," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.
- Gao, F. Y. Ma, B. Zhang, and M. Xian. 2022. "SepNet: A neural network for directionally correlated data," *Neural Networks* 153: 215-223. <https://doi.org/10.1016/j.neunet.2022.06.005>.
- Getto, E., M. Johnson, M. R. Maughan, N. Nathan, J. McMahan, B. Baker. K. Knipling, S. Briggs, K. Hattar, and M. J. Swenson. 2022. "Friction stir welding and self-ion irradiation effects on microstructure and mechanical properties changes within oxide dispersion strengthened steel MA956," *Journal of Nuclear Materials* 567: 153795. <https://doi.org/10.1016/j.jnucmat.2022.153795>.
- Gnaupel-Herold, T., M. Bhattacharyya, I. Charit, K. Raja, J. Darsell and S. Jana. "Stresses Due to Friction Stir Weld Repair of Simulated Cracks in 304L Stainless Steel Plates," presented at American Conference on Neutron Scattering, in: *Structural Materials and Engineering*.



- Jillepalli, A. A., D. C. De Leon, J. Alves-Foss, C. L. Jeffery, and F. T. Sheldon. 2022. "A Formal Model and Verification for HESTIA: An Automated, Adversary-Aware Risk Assessment Process for Cyber Infrastructure," *IEEE Access* 10: 83755-83792. <https://doi.org/10.1109/ACCESS.2022.3197195>.
- Johnson, M., M. Harned, S. B. Adisa, M. Moradi, N. Ehmke, M. R. Maughan, and M. J. Swenson. 2021. "Irradiation-induced microstructure and microchemistry effects on mechanical properties in ferritic-martensitic alloys" *Materialia* 20: 101228. <https://doi.org/10.1016/j.mtla.2021.101228>.
- Mahler, R. L. 2022. "The potential of solar energy to meet renewable energy needs in Idaho, USA," *International Journal of Energy Production and Management* 7(2): 140-150. <https://www.witpress.com/elibrary/eq-volumes/7/2/2904>.
- Makrakis, A., M. Georgios, E. Chatzoglou, G. Kambourakis, and H. Michael. 2022. "Log4J and the Endless Supply of Supply Chain Vulnerabilities," Computer.
- Makrakis, G. M., C. Kolias, G. Kambourakis, C. Rieger, and J. Benjamin. "Industrial and Critical Infrastructure Security: Technical Analysis of Real-Life Security Incidents," *IEEE Access* 9: 165295-165325. <https://doi.org/10.1109/ACCESS.2021.3133348>.
- Maughan, M. R. and D. F. Bahr. 2021. "Critical Issues in MEMS Property Measurement and Variation Measured by Nanoindentation: Error Sources and Uncertainty," *Journal of Microelectromechanical Systems* 31(3): 226-233. <https://doi.org/10.1109/JMEMS.2021.3133792>.
- McLing, T. L., G. Neupane, P. F. Dobson, N. Spycher, M. Conrad, and R. W. Smith. 2020. "Evaluation of Deep Geothermal Resources Using Rare Earth Elements, Snake River Plain, Idaho, USA," presented at World Geothermal Congress 2020+1. www.geothermalenergy.org/pdf/IGAstandard/WGC/2020/11177.pdf
- Miller, E., M. G. M. Makrakis, K. A. Vedros C. Kolias, C. Rieger, D. Barbara. 2022. "Detecting Code Injections in Noisy Environments through EM Signal Analysis and SVD Denoising," 20th Int'l Conf on Embedded Systems, Cyber-physical Systems, and Applications. arXiv:2212.05643. <https://doi.org/10.48550/arXiv.2212.05643>.
- Mohammed, A. A., A. Abuhussein, F. S. Alsubaei, F. T. Sheldon. 2022. "Novel Security Models for IoT-Fog-Cloud Architectures in a Real-World Environment," *Applied Sciences Special Issue Wireless Sensor Networks: Technologies, Applications Prospects* 12(10): 4837. <https://doi.org/10.3390/app12104837>.
- Naskar, A., M. Bhattacharyya, K. S. Raja, I. Charit, J. Darsell, and S. Jana. 2022. "Room Temperature corrosion behavior of plastically deformed AISI 304 stainless steel by friction stir welding in neutral and acidified chloride solutions," *Corrosion Science and Technology* 57(7): 599-612. <https://doi.org/10.1080/1478422X.2022.2105682>.
- Neupane, G., R. W. Smith, T. L. McLing, T. A. Atkinson, J. F. McLaughlin, N. Spycher, and P. F. Dobson. 2022. "Experimental Assessment of Geochemistry of Geologic Thermal Energy Storage (GeoTES) Systems," *Geothermal Resources Council Transactions* 45:1149-1166. <https://publications.mygeoenergynow.org/grc/1034443.pdf>.
- Nunez, L., C. Downey, I. van Rooyen, I. Charit, M. Maughan. "Surface Roughness of Metal Additive-manufactured Single-track Clads," presented at The Minerals, Metals, and Materials Society (TMS) Annual Meeting & Exhibition, Spring 2022.
- Rambur, A., J. T. Russell. 2022. "Classical Molecular Dynamics Study of Layer-by-Layer Melting in LiXKyCl Salt," presented at Idaho Conference on Undergraduate Research, https://scholarworks.boisestate.edu/icur/2022/poster_session/63/.
- Russell, J. 2022. "Geologic Thermal Energy Storage (GeoTES); A grid-scale energy storage solution," presented at Energy Policy Conference.
- Saikat, D., S. Saha, A. T. Priyoti, E. K. Roy, F. T. Sheldon, A. Haque, and S. Shiva. 2022. "Network Intrusion Detection and Comparative Analysis using Ensemble Machine Learning and Feature Selection," *IEEE Transactions on Network and Service Management*. <https://doi.org/10.1109/TNSM.2021.3138457>
- Shi, J., A. Vakanski, M. Xian, J. Ding, and C. Ning. 2022. "EMT-Net: Efficient multitask network for computer-aided diagnosis of breast cancer," presented at International Symposium on Biomedical Imaging (ISBI 2022), Kolkata, India.
- Shi, J., A. Vakanski, M. Xian, J. Ding, and C. Ning. 2022. "EMT-NET: Efficient Multitask Network for Computer-Aided Diagnosis of Breast Cancer," in 2022 IEEE 19th International Symposium on Biomedical Imaging (ISBI), pp. 1-5.
- Spycher, N., C. Doughty, P. F. Dobson, G. Neupane, R. W. Smith, W. Jin, T. A. Atkinson, and T. L. McLing. 2022. "Evaluation of Mineral Scaling during High-Temperature Thermal Energy Storage in Deep Saline Aquifers," *Geothermal Resources Council Transactions* 45:1201-1215.

- Stewart, S., I. Charit, M. John, A. Ralls, M. Misra and P. L. Menezes. 2022. "A Study of Microstructural Evolution and Indentation Characteristics in Laser Shock Peened AISI 304L Stainless Steel," American Nuclear Society Transactions, in: Spent Fuel Storage and Transportation, ANS Annual Meeting.
- Struhs, E., F. Sotoudehnia, A. Mirkouei, M. M. Ramirez-Corredores, and A. G. McDonald. 2022. "Effect of feedstocks and free-fall pyrolysis on bio-oil and biochar attributes." *Journal of Analytical and Applied Pyrolysis* 166: 105616. <https://doi.org/10.1016/j.jaap.2022.105616>.
- Sun, S., M. Xian, A Vakanski, and H. Ghanem. 2022. "MIRST-DM: Multi-Instance RST with Drop-Max Layer for Robust Classification of Breast Cancer", presented at 25th International Conference on Medical Image Computing and Computer Assisted Intervention.
- Vakanski, A. and M. Xian. 2022. "Evaluation of complexity measures for deep learning generalization in medical image analysis," presented at 31st IEEE International Workshop on Machine Learning and Signal Processing.
- van Rooyen, N., M. Bhattacharyya, I. Charit, and M. R. Maughan. 2022. "Indentation investigation of 304L stainless steel friction stir weld simulated crack repair," *Materials Science and Engineering A*, 836: 142691. <https://doi.org/10.1016/j.msea.2022.142691>.
- Vedros, K., G. M. Makrakis, C. Kolas, M. Xian, D. Barbara, and C. Rieger. 2021. "On the Limits of EM Based Detection of Control Logic Injection Attacks In Noisy Environments," 2021 Resilience Week (RWS), Salt Lake City, UT, pp. 1-9. <https://doi.org/10.1109/RWS52686.2021.9611805>.
- Walters, J., A. Mirkouei, and G. M. Makrakis. 2022. "A Quantitative Approach and an Open-Source Tool for Social Impacts Assessment," ASME IDETC/CIE: 27th Design for Manufacturing and the Life Cycle Conference, St. Louis, MO. <http://dx.doi.org/10.1115/DETC2022-89196>.
- Wang, H., M. Xian, and A. Vakanski. 2021. "TA-Net: Topology-aware network for gland segmentation," Winter Conference on Applications of Computer Vision, arXiv:2110.14593. <https://doi.org/10.48550/arXiv.2110.14593>.
- Zhang, B., A. Vakanski, and M. Xian. 2021. "BI-RADS-Net: An explainable multitask learning approach for cancer diagnosis in breast ultrasound images," 31st IEEE International Workshop on Machine Learning and Signal Processing, arXiv:2110.04069. <https://doi.org/10.48550/arXiv.2110.04069>.
- Zhang, Y., M. Xian, H. D. Cheng, B. Shareef, J. Ding, F. Xu, K. Huang, B. Zhang, C. Ning, and Y. Wang. 2022. "BUSIS: A Benchmark for Breast Ultrasound Image Segmentation," *Healthcare* 10(4): 729. <https://doi.org/10.3390%2Fhealthcare10040729>.



**INFORMATIONAL
FEBRUARY 28, 2024**

SUBJECT

Semi-Annual Report of Approved Program Requests

REFERENCE

February 2021	Board received the semi-annual report
August 2021	Board received the semi-annual report
February 2022	Board received the semi-annual report
August 2022	Board received the semi-annual report
February 2023	Board received the semi-annual report
August 2023	Board received the semi-annual report

APPLICABLE STATUTE, RULE, OR POLICY

Idaho State Board of Education Governing Policies and Procedures, Section III.G., Postsecondary Program Review and Approval.

BACKGROUND/DISCUSSION

In accordance with Board Policy III.G.3.a.ii, 3.b., 4.a. and 4.b., prior to implementation, the Executive Director or State Administrator of the Division of Career Technical Education or their designee may approve actions related to academic and career technical programs or units as identified in those subsections. The establishment of a new, or discontinuation of any existing academic undergraduate or graduate certificate consisting of fewer than 30 credits, do not require approval. Per III.G.3.c, institutions are only required to notify the Board office of those new or discontinued certificates within 30 days after implementation.

Consistent with Board Policy III.G.9.a., the Board office is providing a semi-annual report of academic and career technical program requests from Idaho's public postsecondary institutions that were approved by the Board, the Executive Director or State Administrator, or their designee between July 1, 2023, and December 31, 2023.

ATTACHMENTS

Attachment 1 – Semi-Annual Report of Approved Program Requests

Attachment 2 – List of Program Approvals and Discontinuations

BOARD STAFF COMMENTS AND RECOMMENDATIONS

The report provides a list of new academic or career technical programs and certificates approved by the Executive Director or State Administrator or their designee consistent with Board Policy III.G. This includes other instructional activity such as modifications to existing programs. Other non-substantial changes that require notification to the Board office are also included in the report.

For this current reporting cycle, there were fewer program requests submitted for review and approval. Although, notably, the Board approved three new applied baccalaureate degrees in December from College of Eastern Idaho and College

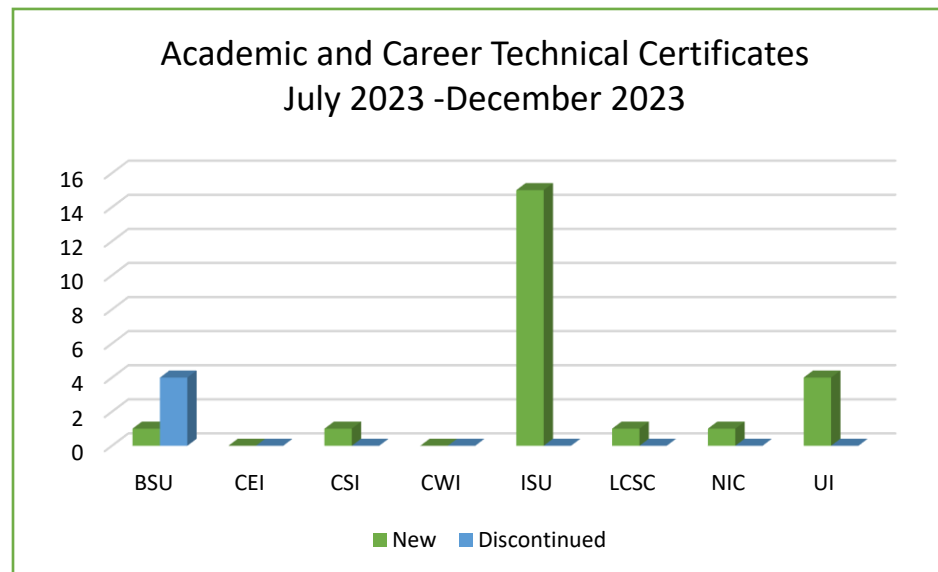
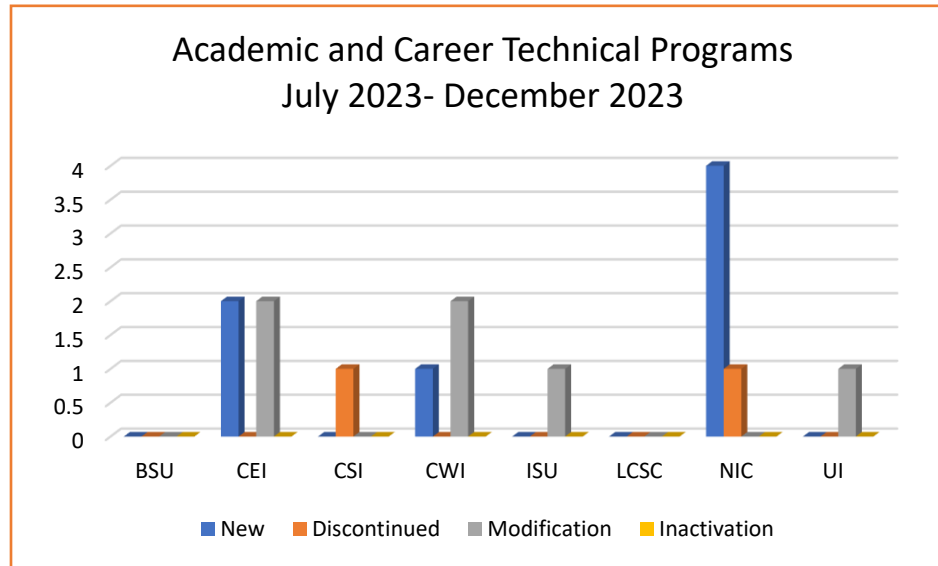
**INFORMATIONAL
FEBRUARY 28, 2024**

of Western Idaho. The other new programs shown are associate of applied science apprenticeship programs from North Idaho College. Staff notes there were more certificates established versus degree programs in general and fewer discontinuations. Staff will update charts in Attachment 1 and provide a comprehensive annual trend analysis in August 2024.

BOARD ACTION

This item is for informational purposes.

**Semi-Annual Report of Approved Program Requests
July 2023 through December 2023**



List of Academic Program and Unit Requests Approved by Executive Director or Designee

INST.	Request Type	Program Title	Type	Date
NIC	New	Construction Management	AS	11/27/2023
LCSC	New	General Education Completion	Certificate	11/8/2023
CWI	Modification	Unit - Science, Technology, and Math	N/A	10/13/2023
CWI	Modification	Unit - Agricultural Sciences; Physical Sciences	N/A	10/13/2023
ISU	Expansion	Didactic Program in Dietetics: expansion to Treasure Valley	BS	9/29/2023
CSI	Discontinuance	Education, Early Childhood Education	AA	9/15/2023
NIC	Discontinuance	American Sign Language	AA	8/7/2023

List of Other Academic Program/Unit Changes Notified to Executive Director

The following program changes or additions do not require approval; however, they require notification to OSBE per policy III.G.

INST.	Request Type	Program Title	Certificate Type	Date
ISU	New	Conflict Management	Certificate	12/21/2023
ISU	New	Digital Graphic Design	Certificate	12/21/2023
ISU	New	Sports Media	Certificate	12/21/2023
ISU	New	Social Media	Certificate	12/21/2023
ISU	New	Advocacy	Certificate	12/21/2023
ISU	New	Organizational Leadership	Graduate Certificate	12/21/2023
ISU	New	Human Resource Development	Graduate Certificate	12/21/2023
ISU	New	Homeland Security & Emergency Management (online)	Graduate Certificate	12/20/2023
ISU	New	Environmental Studies	Graduate Certificate	12/20/2023
BSU	New	Generative AI	Undergraduate Certificate	12/19/2023
ISU	New	Supply Chain Management	Academic Certificate	12/6/2023
ISU	New	Theatre: Simulated Participant Actor	Certificate	12/6/2023
BSU	Discontinuance	Mechanical Materials	Undergraduate Certificate	12/1/2023
BSU	Discontinuance	Industrial Processes	Undergraduate Certificate	12/1/2023
BSU	Discontinuance	HVAC/Building Systems	Undergraduate Certificate	12/1/2023
BSU	Discontinuance	Energy/Environment certificate	Undergraduate Certificate	12/1/2023

**INFORMATIONAL
FEBRUARY 28, 2024**

ATTACHMENT 1

INST.	Request Type	Program Title	Certificate Type	Date
ISU	New	Cultural Resources Management	Academic Certificate	11/27/2023
ISU	New	Environmental Studies	Academic Certificate	11/27/2023
ISU	New	Technical Communication	Undergraduate Certificate	11/27/2023
UI	New	Professional Skills in Chemical Addictions Counseling	Certificate-UG	11/20/2023
UI	New	Chemical Addictions: Principles and Practice	Certificate-UG	11/20/2023
UI	New	Aerospace	Certificate-UG	11/20/2023
UI	New	Sustainability	Certificate-UG	11/20/2023
ISU	New	Forensic Sciences	Graduate Certificate	8/10/2023

Other Academic Program Changes

INST.	Request Type	Program Title	Program Type	Date
ISU	Discontinuance	Advocacy	Minor	12/21/2023
ISU	Discontinuance	Advocacy (online)	Minor	12/21/2023
ISU	Discontinuance	Social Media	Minor	12/21/2023
ISU	Discontinuance	Social Media (online)	Minor	12/21/2023
BSU	New	Legal Studies	Minor	12/19/2023
BSU	New	Public Humanities	Minor	12/19/2023
BSU	New	Early Childhood Leadership	Emphasis	12/19/2023
BSU	New	Resort and Hospitality Management	Emphasis	12/19/2023
BSU	New	Business Administration	Emphasis	12/19/2023
BSU	New	Sport Media and Communications	B.A. emphasis	12/19/2023
BSU	Change Name	Biomolecular Research Center to Biomolecular Research Institute	N/A	12/19/2023
ISU	CIP Codes	Change CIP code for Professional Sales certificate to 52.1804	Academic Certificate	12/13/2023
CWI	CIP Codes	Change CIP code for the following programs: • Biology – Human Biology emphasis • Business • Entrepreneurship & Small Business Management	AS AA AA	12/6/2023
BSU	Discontinuance	Spanish Interpretation	Minor	12/1/2023
BSU	New	Spanish for Professions	B.A. emphasis	12/1/2023
ISU	Expansion	Transition existing Master of Public Health to fully online	Master	11/30/2023

**INFORMATIONAL
FEBRUARY 28, 2024**

ATTACHMENT 1

INST.	Request Type	Program Title	Program Type	Date
ISU	Expansion	Transition existing certificate in Public Health to fully online	Graduate Certificate	11/30/2023
ISU	Discontinue	Folklore	Minor	11/21/2023
ISU	Discontinue	Discontinue emphases under the following programs: - Accounting, B.B.A. - Data Analytics Emphasis - Accounting, B.B.A. - Operations Management Emphasis - Economics, B.B.A. - Data Analytics Emphasis - Economics, B.B.A. - Operations Management Emphasis - Finance, B.B.A. - Data Analytics Emphasis - Finance, B.B.A. - Entrepreneurship/Small Business Emphasis - Finance, B.B.A. - Operations Management Emphasis - General Business, B.B.A. - Data Analytics Emphasis - General Business, B.B.A. - Operations Management Emphasis - Management, B.B.A. - Data Analytics Emphasis - Management, B.B.A. - Entrepreneurship/Small Business Emphasis - Management, B.B.A. - Human Resources Management Emphasis - Management, B.B.A. - Operations Management Emphasis - Marketing, B.B.A. - Data Analytics Emphasis - Marketing, B.B.A. - Entrepreneurship/Small Business Emphasis - Marketing, B.B.A. - Operations Management Emphasis	B.B.A. emphases	11/21/2023
UI	Discontinuance	International Business	Minor	11/20/2023
UI	Expansion	Interdisciplinary Studies (online)	B.A. B.S.	11/20/2023
BSU	Change type	Change the following options to emphases under the BS in Advanced Medical Imaging - Computed Tomography - Magnetic Resonance Imaging - Interventional Cardiology - Diagnostic Medical Sonography - Interventional Radiology	BS	11/20/2023
BSU	Change location	Move minor in Critical Theory from College of Arts and Sciences to Department of Humanities and Cultural Studies under the same college.	Minor	11/20/2023

**INFORMATIONAL
FEBRUARY 28, 2024**

ATTACHMENT 1

INST.	Request Type	Program Title	Program Type	Date
LCSC	New	Business Administration Healthcare Management emphasis	B.A./B.S. emphasis	11/13/2023
NIC	CIP Codes	Changes to the following programs: • Business 52.02.01 • Education 13.1205	AS AA	10/10/2023
ISU	New	Interdisciplinary Environmental Social Science concentration under the existing MA in Sociology	MA concentration	7/24/2023
ISU	Name change	Change Department of Mechanical Engineering to Mechanical and Measurement & Control Engineering	N/A	7/24/2023
BSU	Change location	Move Human-Environment Systems Graduate Certificate from the College of Innovation and Design to the College of Arts and Sciences in the School of the Environment	N/A	7/7/2023
BSU	Change location	Move BS in Games, Interactive Media, and Mobile program from the College of Innovation and Design to the College of Arts and Sciences	N/A	7/7/2023

List of Career Technical Program Requests Approved by State Administrator (by Type)

INST.	Request Type	Program Title	Program Type	Date
ISU	New	Medical Assisting	ITC	12/20/2023
CEI	Modification	Registered Nursing	AAS	11/28/2023
CEI	Modification	Practical Nursing	ITC	11/28/2023
CSI	Expansion	Agriculture	BTC	11/28/2023
CWI	Modification	Bookkeeping and Accounting (moving to online)	AAS	11/16/2023
CWI	Modification	Medical Administrative Support (moving to online)	BTC	11/16/2023
NIC	New	Applied Technology and Apprenticeship - HVAC	A.A.S.	8/17/2023
NIC	New	Applied Technology and Apprenticeship - Plumbing	A.A.S.	8/17/2023
NIC	New	Applied Technology and Apprenticeship - Electrical	A.A.S.	8/17/2023
NIC	New	Computer Control Automation Technology	ITC	7/27/2023

List of Other CTE Program Changes Notified to State Administrator

The following program changes or additions do not require approval; however, they require notification to OSBE per policy III.G.

INST.	Request Type	Program Title	Degree	Date
ISU	Discontinuance	Discontinue Veteran to Nurse Option and Traditional Option under the Practical Nursing Program	ITC	12/18/2023
CWI	CIP Codes	Change CIP code for Physical Therapist Assistant to 51.0806	AAS	12/6/2023
CSI	Name change	Cabinet/Woodworking to Woodworking Technology	BTC, ITC, AAS	11/21/2023
LCSC	Name change	Change Administrative Medical Assistant to Medical Administrative Assistant	ATC, AAS	11/21/2023
LCSC	Name change	Applied Accounting to Bookkeeping/Accounting	AAS, ATC	11/9/2023
NIC	CIP Codes	Changes to the following programs: - Mechanical Design Engineering Technology 15.1307 - Virtual Administrative Assistant 52.0401	AAS, ATC, ITC ITC	10/10/2023
CSI	Discontinuance	Quality Assurance and Automation and Controls options under the Food Processing Technology program	BTC, ITC, AAS	10/5/2023
CWI	Name change	Change Transportation Technology department to Automotive Service and Collision Repair	N/A	10/6/2023
CWI	Name change	Change Diesel Technology department to Powersports and Diesel Technology	N/A	10/6/2023
CSI	CIP Codes	Changes to the following programs:	CIP Codes	8/10/2023

**INFORMATIONAL
FEBRUARY 28, 2024**

ATTACHMENT 1

INST.	Request Type	Program Title	Degree	Date
		• Computer Support Technician – ITC 11.1006 • Cyber Security and Programming – AAS 11.1003 • Applied Technology & Apprenticeship – Plumbing 46.0503 • Applied Technology & Apprenticeship - Maintenance Tech 47.0303 • Residential Construction – BTC 46.0415 • Diesel Technology – AAS 47.0613 • Diesel Technology – ITC 47.0613 • Machining & Manufacturing Technology – AAS 48.0501 • Machining & Manufacturing Technology – ITC 48.0501 • Machining & Manufacturing Technology – BTC 48.0501 • Outdoor Recreation Leadership – BTC 31.0601 • Outdoor Recreation Leadership – ITC 31.0601 • Heavy Equipment Ag Technology – ITC 47.0302 • Heavy Equipment Ag Technology – AAS 47.0302 • Agriculture – AAS 01.0301 • Introduction to Cybersecurity - BTC 11.1003 • Agriculture – BTC 01.0301 • Visual and Performing Arts - AA 50.0101 • Outdoor Recreation Leadership - AA 31.0601 • Natural Resources Management - AS 03.0201		

List of Academic Program Requests Approved by the Board

INST.	Request Type	Program Title	Degree	Date
CEI	New	Operations Management	BAS	12/18/2023
CEI	New	Digital Forensics and Analytics	BAS	12/18/2023
CWI	New	Business Administration	BAS	12/18/2023

INFORMATIONAL
FEBRUARY 27-28, 2024

IDAHO BUREAU OF EDUCATIONAL SERVICES FOR THE DEAF AND THE BLIND

SUBJECT

Idaho Bureau of Educational Services for the Deaf and the Blind (IBESDB) Annual Report

February 2019	IESDB provided the Board with a report updating the Board with current progress of the Bureau.
February 2021	IESDB provided the Board with a report updating the Board with current progress of the Bureau.

APPLICABLE STATUTE, RULE, OR POLICY

Sections 33-3405(4) and 33-3411, Idaho Code

BACKGROUND/DISCUSSION

Pursuant to Idaho Code § 33-3405(4) the administrator of IBESDB shall make an annual report of the Bureau's activities to the State Board of Education at a time and in a format designated by the Board. While IBESDB was moved out from the Board's direct governance in 2009, the Board retains rulemaking authority for education services for students who are deaf or hard of hearing and/or blind or visually impaired, as well as property rights for the School for the Deaf and Blind.

The Idaho Bureau of Educational Services for the Deaf and Blind, originally the Idaho School for the Deaf and Blind, has been providing services to Idaho's children since 1906. Their programs consist of statewide outreach programs and the Idaho School for the Deaf Blind, located in Gooding Idaho. They provide supplemental education services, early intervention and education, consultation, and transition support to families and local school districts throughout Idaho. The property in Gooding that houses the School for the Deaf and Blind is held by the State Board of Education and leased back to IBESDB for their use.

IBESDB presented this report at the Planning, Policy and Government Affairs committee meeting on February 5, 2024. The written report is included in these materials for the Board's review.

IMPACT

This annual update will provide the Board with an update on the scope of IBESDB's efforts to serve Idaho's children.

ATTACHMENTS

Attachment 1 – IBESDB Annual Report

BOARD ACTION

This item is for informational purposes only.

Idaho Bureau of Educational Services for the Deaf and
the Blind

OSBE REPORT 2024



****Idaho Educational Services for the Deaf and the Blind: A Legacy of Inclusivity and Excellence****

Established in 1906 to address Article X of the State Constitution, the Idaho Bureau of Educational Services for the Deaf and the Blind (IBESDB) has evolved into a unique institution. Rooted in the commitment to support individuals with sensory impairments, IBESDB serves as one of the 12 dual schools in the United States.

****Historical Journey and Organizational Structure:****

- Initially a State Agency, The IBESDB transitioned in 2009 to operate under its own Board of Directors, chaired by the State Superintendent of Public Instruction.
- Governed by State Statute 33-3400, the bureau aims to ensure accessibility, quality, and equity for students with sensory impairments, tailoring services based on individual educational needs rather than the level of hearing or vision loss.

****Continuum of Services:****

- IBESDB caters to 2,600 students across its continuum, a significant increase from the 1,100 students served in 2009, when it was first established.
- Two distinct departments, "Outreach" and "Campus," along with support services, facilitate a comprehensive approach to education.

****Outreach Department:****

- Seven regional Education Centers, serving students from Birth to age 21.
- Certified teachers, covering 13,000 miles on average, provide services, materials, and technology to their respective regions including families, public and charter school personnel.
- Early intervention programs have witnessed substantial growth, exemplified by increased enrollment in Deaf/Hard of Hearing and Blind/Low Vision categories. Giving all of our kids a good head start.
- Summer offerings for students on work development skills and experiential learning.

****Campus Department:****

- Established in 1906, the campus of the Idaho School for the Deaf and the Blind (ISDB) spans 40 acres in Gooding, featuring a 140,000 sq. ft. primary building and six cottages hosting 63 residential students.

Presented by:
Brian G. Darcy, Administrator
Idaho Educational Services for the Deaf and the Blind
1450 Main St.
Gooding, ID 83330
brian.darcy@iesdb.org
ph. (208) 934-4457 cell/text: (208) 963-0671 VP: (208) 944-2503 Fax: 208-934-8352





Idaho Bureau of Educational Services for the Deaf and the Blind

OSBE REPORT 2024

- Serving preschool to age 21, Campus collaborates with local schools, ensuring no student commutes for more than 3.5 hours.

****Educational Approach and Accomplishments:****

- ISDB students are primarily on individualized education plans (IEPs), acknowledging the diverse needs of students and the complexity of approaches needed in the classroom.
- The institution embraces flexibility in teaching strategies, extending beyond academics to residential life and extracurricular activities.
- Integration of mental health programs and Positive Behavior Intervention Supports (PBIS) through the "CLAW" program, underlines a holistic approach to student development.
- "BridgeE" which is the 18-21 program and focusses on development of independent living skills and focusses on building employment ready adults. Operates a working food truck in the community.
- Provides an educational environment where students can engage with peers and educational staff directly, while developing skills beyond the 3 "r's" to become model citizens of Idaho.

****Facilities and Recent Projects:****

- The 116-year-old campus undergoes continuous improvements, with recent projects including bathroom renovations, fire alarm overhauls, a fully accessible playground, parking lot re-pavement, and track renovations.
- Ongoing recommendations before the Permanent Building Fund Advisory Committee include new cottages, ADA accessibility enhancements, and parking lot improvements.
- Collaborative efforts with the Permanent Building Fund Advisory Committee and the Department of Public Works ensure the preservation and enhancement of the campus.

****Community Engagement:****

- IBESDB fosters a positive school climate through initiatives like the Raptor buck system, school-wide events, spirit weeks, and CLAW News.
- Leasing of unused space, which is approved by OSBE, to various stakeholder groups, brings local community members to campus and to engage with our students and staff.

In summary, the Idaho Bureau of Educational Services for the Deaf and the Blind stands as a beacon of inclusive education, continuously adapting to the evolving needs of its diverse student population. Through its rich history, commitment to excellence, and collaborative spirit, IBESDB remains dedicated to developing compassionate leaders who advocate for themselves and others, embodying the institution's mission and vision.

**PLANNING, POLICY AND GOVERNMENTAL AFFAIRS
FEBRUARY 27-28, 2024**

IDAHO STEM ACTION CENTER

SUBJECT

Idaho STEM Action Center Annual Report

APPLICABLE STATUTE, RULE, OR POLICY

Idaho Code § 67-823

BACKGROUND/DISCUSSION

Section 67-823, Idaho Code establishes within the office of the governor a Science, Technology, Engineering, and Math Action Center (STEM Action Center). The STEM Action Center is tasked with coordinating and overseeing STEM programs, to promote best practices in STEM education, and to make recommendations to the Board regarding the issuance of STEM School Designations pursuant to Idaho Code § 33-4701.

Idaho Code § 67-823 further requires that the STEM Action Center make an annual report to the governor, legislature, and state board of education.

Caty Solace, Executive Director of the STEM Action Center, presented the organization's annual report at the Planning, Policy and Government Affairs committee meeting on February 5, 2024. The written report is included in these materials for the Board's review.

IMPACT

This annual update will provide the Board with an update on the scope of the Idaho STEM Action Center's efforts to serve Idaho's children.

ATTACHMENTS

Attachment 1 – Idaho STEM Action Center Annual Report

BOARD ACTION

This item is for informational purposes only.



IDAHO
STEM
ACTION CENTER

Presenting to: Idaho State Board of Education

February 5, 2024– Caty Solace

Vision:

A diverse STEM-literate Idaho workforce that meets the changing needs of Idaho employers and supports the long-term economic prosperity of Idaho.

Mission:

Providing coordination for statewide STEM education and activities to enhance opportunities for educators, students, communities, and employers in their work to build a competitive Idaho workforce and economy through STEM and computer science education.

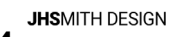


Idaho's Economy & Jobs

- Idaho STEM jobs are projected to **grow 15.4%** by 2030 outpacing the national estimated growth at 10.5%.
- Some of **Idaho's biggest industries** increasingly rely on STEM-skilled workers- jobs in advanced manufacturing, skilled trades, agriculture, software development, cybersecurity, and health care, just to name a few.
- STEM jobs **pay nearly double** the median wage of non-STEM jobs in Idaho, setting our students up for financial success.

INFORMATIONAL
FEBRUARY 27-28, 2024

ATTACHMENT 1



It takes a village!



ZIONS BANK.



kiln.



INFORMATIONAL - PGA



TAB 4 Page 4 Mountain View Hospital



Idaho STEM Action Center Advisory Board

- Jennifer Jackson, Board Chair
 - K-12 STEM Program Manager, Idaho National Laboratory
- Ed Atienza, Vice Chair
 - Research and Development Engineering Manager, Schweitzer Engineering Laboratories
- Dee Mooney
 - Executive Director, Micron Foundation
- Dr. David J. Hill
 - Idaho State Board of Education
- Jad Mahnken
 - Recruiter, Saint Alphonsus
- Jake Reynolds
 - Business Development and Operations Admin, Idaho Department of Commerce
- Wendi Secrist
 - Executive Director, Idaho Workforce Development Council
- Steve Christiansen
 - Vice President of Human Resources & Organizational Development, Idaho Milk Products
- Allison Duman
 - K-12 Workforce Project Specialist, State Department of Education

Alignment with Legislation:

Coordination of STEM Activities

- Leadership of the Workforce and Education Consortium (Advanced Manufacturing)
- Leading Standard Committee for Early Childhood Development in STEM Apprenticeship



High Quality STEM Professional Development

- i-STEM and other PD programs (711 participants in 7/22-6/23)
- Teacher Extern Program (expanded program from 24-86 educators summer of 23)
(In partnership with Micron and Idaho Workforce Development Council)

Statewide Learning Platforms

- Learning Blade (over 285,000 online lessons completed by 9,000 students)

STEM School Designation

- 11 STEM Designated Schools; new standards for this year which were approved by the State Board in Nov.

Computer Science

- Computer Science Week Hour / Hour of Code (80 Hour of Code events statewide)
- Co-leading Computer Science Standards review with State Department of Education

Sponsorship of STEM Ecosystem

- “Boots on the Ground” STEM Activity support at the local and regional level 3,650 student interactions in the first 6 months

Looking to the future!

- Update of the Statewide STEM Education Strategic Plan
- Updated model for STEM-related Public Private Partnerships
- Continued efforts to better align with legislation
- Continued process improvement for existing programs
- Building deeper and better-defined partnerships with state agencies operating in the STEM sphere





IDAHO
STEM
ACTION CENTER

Thank you!

Caty Solace
caty.solace@stem.idaho.gov
208.332.1726