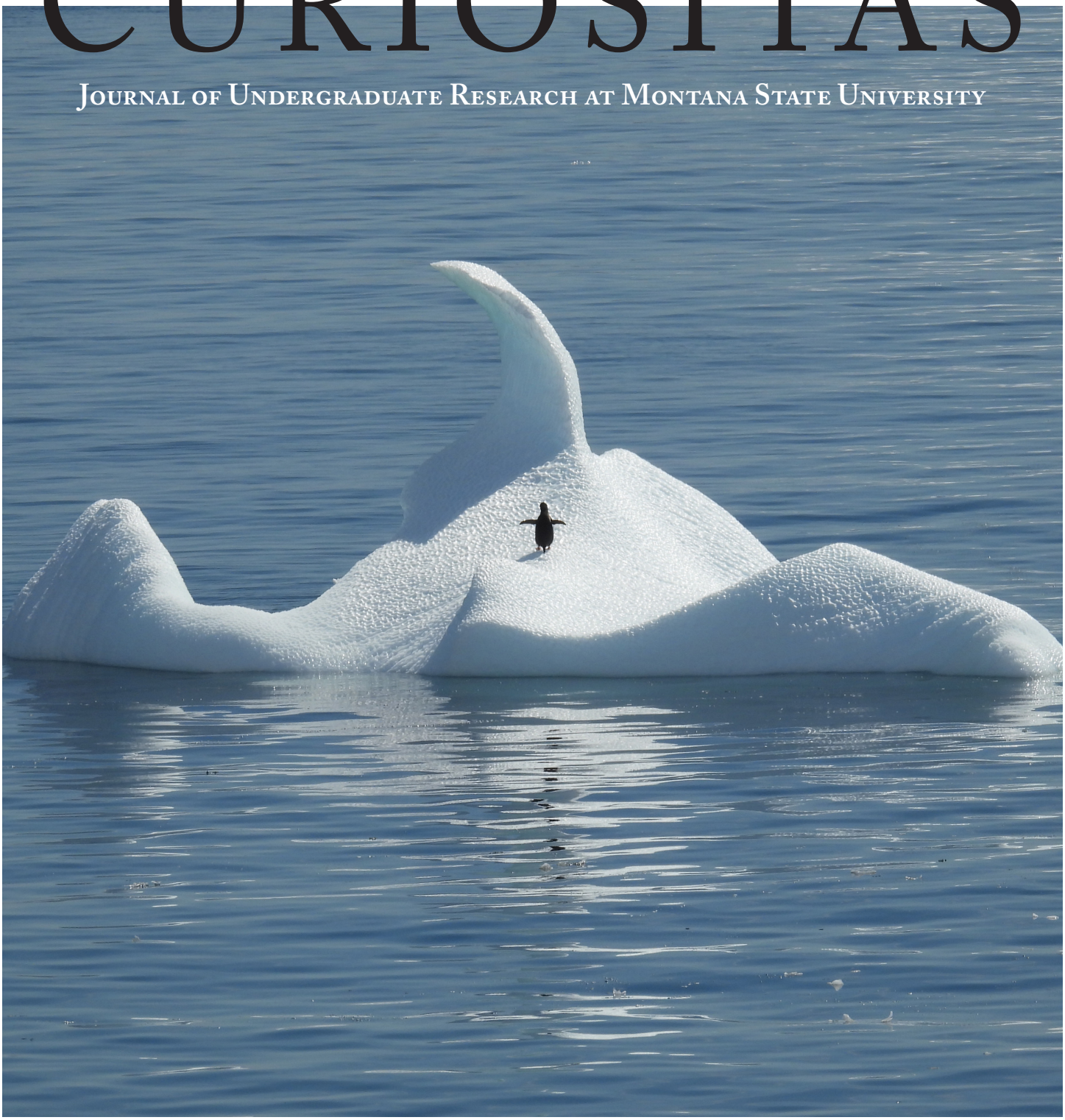
Cover Photo by Isabel Colvin

Spring 2026

CURIOSITAS

Journal of Undergraduate Research at Montana State University



Gentoo Penguin Photos

By Isabel Colvin

Abstract

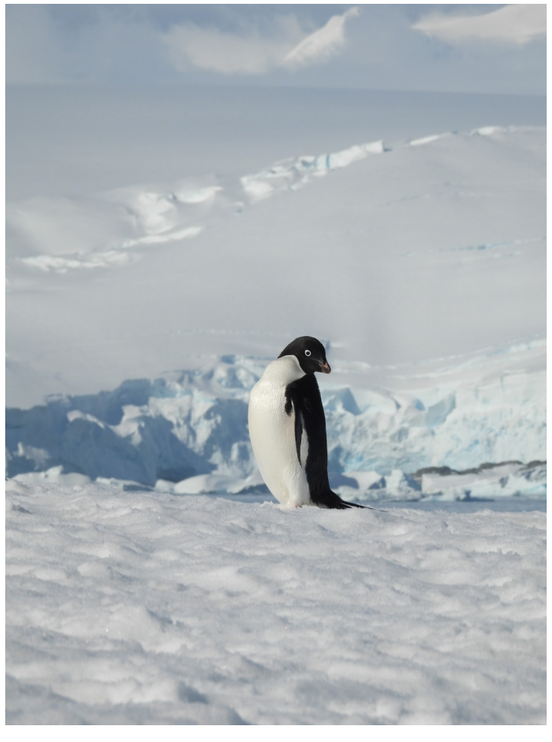
I went to Antarctica with the University of Denver this winter to photograph and observe Antarctic wildlife in different habitat types as part of an independent project. Antarctica is a beautiful continent, and I was very lucky to visit and capture the behaviors and special moments among the penguins I witnessed. Antarctica has a very quiet and fragile ecosystem. Krill reside lowest on the food chain but also are a keystone species that feed everything from small fish and penguins to massive leopard seals and whales. Without krill, the ecosystem would collapse.

The most reliable animals that I encountered were penguins. Both Adelie and Gentoo penguins are members of the brushed-tail penguin family. December is peak penguin mating season, and penguins are very busy collecting pebbles to build their nests and impress their partners with songs and displays of affection in courtship rituals. All penguins are monogamous and mate with the same penguin every season, and both parents take turns sharing parental duties and building their nest. Some of my favorite and most charismatic species I photographed were the wide-eyed Adelies and the social Gentoo penguins. When I saw penguins doing "penguin things" like jumping onto an iceberg, being deep in a courtship ritual, or lone penguins looking silly in the most gorgeous place on earth, I wanted to capture what I was observing.

I miss the penguins, but looking at these photos reminds me of the beautiful life they have on their frozen continent.

About the Author

Isabel (Izzy) Colvin is a senior at Montana State University graduating this spring with a degree in Fish and Wildlife Ecology Management. She hopes to someday be a wildlife biologist in Yellowstone National Park and work with megafauna on the landscape ecology level. Originally from Milwaukee, Wisconsin, she loves to travel and study abroad. Izzy enjoys running, watching and photographing wildlife, and skiing. When she's not out in the wilderness looking for animals, she is looking at dinosaurs in the Museum of the Rockies.



Dear MSU Community,

We are proud to share with you this year's edition of Curiositas, Montana State University's undergraduate research journal. This publication celebrates the breadth and depth of original research conducted by MSU undergraduates across an array of academic disciplines.

Curiositas is the result of cross-campus collaboration. As part of the Undergraduate Research Council, the journal embodies MSU's commitment to giving voice to student researchers by expanding access to research publication and ensuring the long-term sustainability of this platform for future scholars.

We would like to thank the students and faculty mentors whose passion and dedication has made this journal possible. We would also like to thank the National Science Foundation's ART program as well as the Undergraduate Scholars Program and Doug Downs for their contributions and support!

Enjoy inspiration and discovery in the pages of this year's journal.

Warmly,

The Editorial Board
Curiositas
Montana State University

Photo courtesy of Dr. Nika Stoop
Pictured from left to right — back row: Ben Kosel and Lukas Kosel; front row: Jessminda DiCello, Calista Pyrak, and Taylor Pooton.

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ESTABLISHED 2020
MONTANA STATE UNIVERSITY

TOPOTiLE

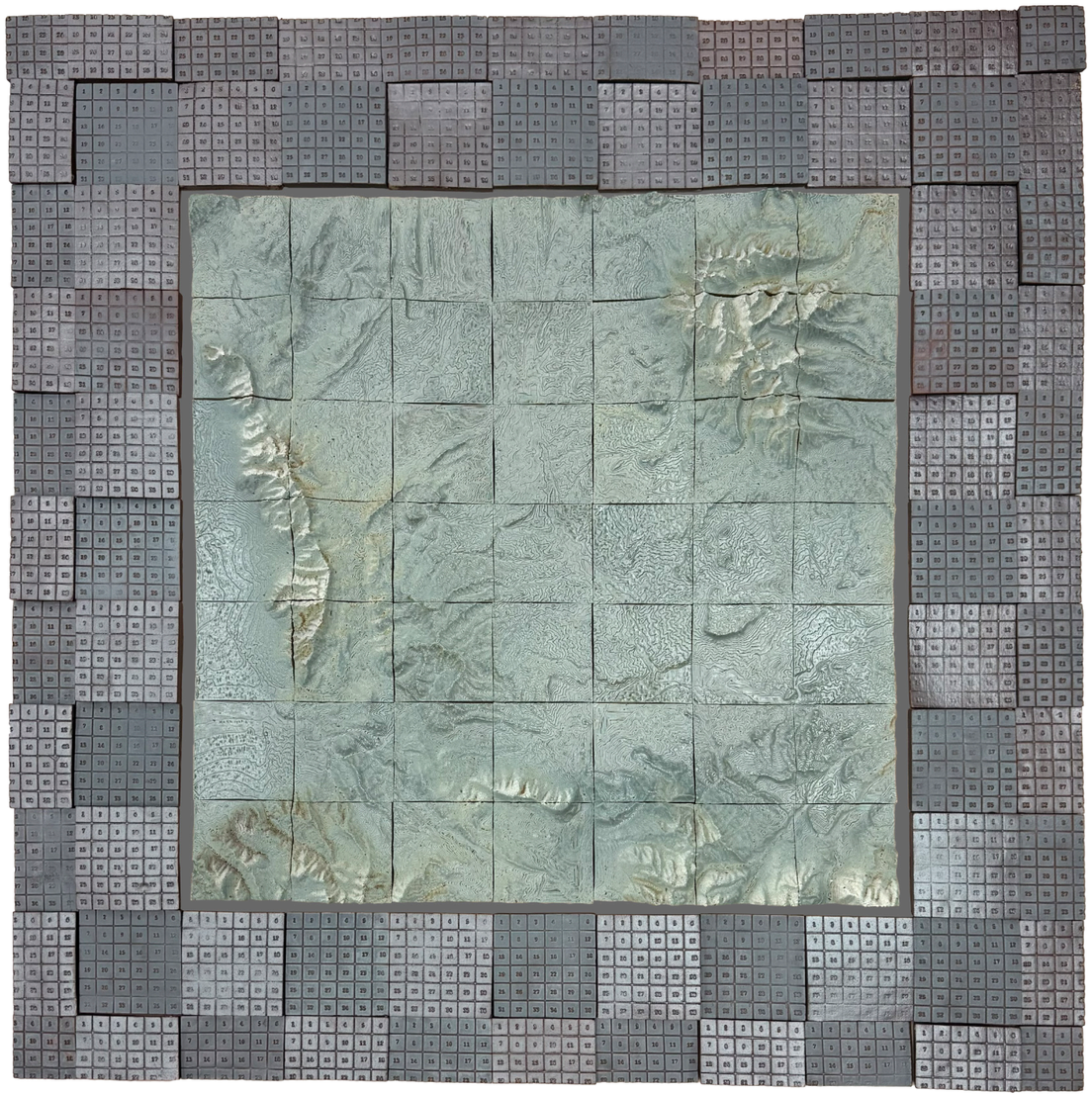
By Garrett Dominick

Artist Statement

One of my main objectives with my ceramic art is to create objects with qualities that would be often considered counterintuitive or unattainable with clay. I utilize standard plastic 3D printing to develop and create unique tools that aid in the precision required for complex mechanical systems. Most recently I have been using a clay 3D printer to print gears, levers, ratchets, ball and socket joints, brackets and other mechanical elements that are incorporated in my pieces. I purchased my clay 3D printer with funding from USP for a summer research project in which I proposed researching the application of ceramics in machine systems. The piece featured in this magazine is titled "TOPOTiLE" and is a result of my investigation in clay 3D printing. TOPOTiLE is a three-foot by three-foot ceramic tile art piece, composed of 121 tiles. I created this piece for a submission to a contest in which the winners are permanently installed in the new School of Computing building, Gianforte Hall. The blue topography tiles are all 3D-printed from clay. The light blue glaze on the topography is composed of a wild clay that is harvested from a location just outside of Helena, MT. The outer border tiles are slab built and stamped with a six by six, numbered grid, which was how the land was sectioned when Montana was first settled and still exists today. The border is glazed in a checkerboard pattern, which is a reference to how Montana was initially divided when the railroad received half of the land. I spent around five to six hundred hours on this project, most of which was working in the software to get the printer to behave exactly as I wanted and to be very repeatable in order to achieve consistent results over the course of printing all 49 tiles. This level of involvement in the 3D-printing process was totally new to me. I learned by experimenting with software settings, observing the results, and adjusting them in real time. I taught myself CAD tools including Blender, Cura, Tinkercad, and Rhino. Adapting an ecosystem of tools and processes designed for plastic 3D printing and CNC milling to work with clay has been challenging, but that difficulty has pushed me to develop a much deeper understanding of the material's behavior and limitations. TOPOTiLE has been acquired by MSU and will be permanently exhibited in Gianforte Hall. It will be available for viewing after the completion of this building in summer of 2026. The most comprehensive publicly available catalog of my art is on my Instagram @GDDCERAMICS.

About the Author

Garrett Dominick is a visual artist who grew up in rural Montana and studies in MSU's Ceramics program, drawn by the unlimited possibilities of clay and the community found in ceramics studios and wood firings. He uses a clay 3D printer to construct elaborate mechanical systems from clay, and in 2025, was awarded a USP Summer Research Grant to research the mechanical qualities of ceramic alongside his mentor, Jeremy Hatch. Dominick's 3x3 foot topographic piece, composed of 121 tiles created by 3D clay printing, will be permanently exhibited in the Gianforte computer science building. Dominick also has won a scholarship for an Arrowmont School for Arts and Crafts glass casting workshop.



Exploring Trust through the Lens of Wildlife Coexistence and Revitalization

By Jonni SpottedEagle

Wildlife coexistence is a way of understanding how humans and wildlife can exist together in shared landscapes through processes of management to mitigate conflicts. Through a reflection on a summer internship in the Blackfeet Nation, Jonni SpottedEagle recounts a journey of personal growth and explores themes of trust while examining how people are re-learning to coexist with bison across Montana. Jonni, an undergraduate student at Montana State University in the Department of Microbiology and Cell Biology, joined Dr. Madison Stevens on her "Restoring Human-Wildlife Coexistence in Working Landscapes" project in the Summer of 2025. This project explores efforts to bring free-roaming buffalo (bison) back to the grasslands and Rocky Mountain front. Under the mentorship of Dr. Stevens, Jonni participated in interviews and fieldwork, exploring how bison reintroduction is a stepstone to cultural revitalization of Indigenous communities who have a shared history with bison, and how the restoration of bison in these landscapes can restore ecosystems. She saw both the positive and negative impacts of bison reintroduction in livestock communities, and in community health and wellness. She recounts how her experience has changed her preconceived notions of what research looks like, and has supported her continued personal and professional growth.

It was during a spontaneous drive with Kim Paul, a prominent figure in the Blackfeet community, through beautiful Glacier National Park, that we came to an abrupt stop on the winding road as a bobcat peeked out of the brush. As the fading sunlight filtered through the trees, the golden light ignited the patterns and cool tones of its fur. It sauntered back into the thicket of trees, and just as it had appeared, it was gone. Here in Montana, we are lucky to live alongside abundant wildlife, yet not all wildlife are easy to live with. Across the world, coexistence with wildlife is a pressing challenge in both rural and urban settings, often raising the question: As society grows and evolves, how does this impact how people interact with animals in modern environments, and what does this mean for communities re-learning to live with animals like a cultural keystone species, buffalo, who are finally returning home after more than a century?

In the summer of 2025, Zahara Thompson and I, two undergrad students and Hilleman Scholars completing our first year at Montana State University, joined Dr. Madison Stevens (Assistant Professor, Earth Sciences) on the National Science Foundation-funded "Restoring Human-Wildlife Coexistence in Working Landscapes" project. This project explores efforts to bring free-roaming buffalo (bison) back to the grasslands and Rocky Mountain Front, promising to restore ecosystems and support Indigenous cultural revitalization. As important as they are, buffalo can also be difficult neighbors, and they are returning to radically changed landscapes. So, my question is: how can we learn to coexist with this keystone species again? Zahara and I joined this research project as summer internship research assistants, where we explored themes of trust, connection, resilience, and personal growth as we delved into the world of environmental social sciences. The interviews we conducted made us rethink what we once thought we knew and allowed us the honor of hearing the amazing stories of people across Montana. Our experiences participating in field trips and community events highlighted the importance of learning through hands-on experience and showed how communication between all groups of people is needed to grow a new definition for coexistence.

This project felt close to home. My name is Jonni SpottedEagle, and I grew up in Browning on the Blackfeet Reservation of Montana. I am currently an undergraduate student at Montana State University, majoring in Microbiology on a pre-med track. What drew me to the project was the ability to explore my Blackfeet culture and to find ways to better community health and wellness through cultural revitalization. Through this research opportunity, I was able to be more involved and connect with members of the community who have similar values of uplifting our community. When I first looked at the project, I saw an opportunity. I was hesitant at first, unsure if this was the right fit for me. I had preconceived notions of what research was and how it was conducted. I expected formality and mountains of paperwork, but as I grew, I found that it was so much more than that.

I was joined in the research by Zahara Thompson, a wildlife ecology student from Missoula, Montana, who sought to better understand the human dimensions of wildlife management. For Zahara, it was eye-opening to learn about how perspectives varied: "I'm realizing it's so important to talk to people and hear their opinions, because you need to understand what people actually want." As Zahara immersed herself in the practices of the community, she listened to the stories of the Blackfeet Elders, learning to develop her interview skills and how to navigate a totally new experience outside her cultural context. She embraced new experiences with an open mind and realized that being a part of the conversation may be difficult but necessary.

A question we asked ourselves throughout this project was: What needs to happen for people (and our cows!) to coexist with the bison on the landscape? Bison are controversial, sparking challenging conversations within the livestock community and complicated state, federal, and Tribal politics, especially in Montana. Competition for land and water resources, with limited options for the bison to roam and the potential risk of disease to the cattle that graze those lands are some of the major concerns. Connections between communities and local politics can be extremely delicate, with many voices and perspectives—a loud minority can easily sway the way a community thinks about a topic. This emerged as one of the many branches of the research, as we saw how trust between the local government and its people can affect policies regarding coexistence not just with bison, but all wildlife across Montana. When it comes to the great and mighty bison, the push for coexistence and reconnection can be seen in the Tribes of Montana, many of which already care for herds of bison. The bison are a connection to a long history of Indigenous people of Montana. As we talked to people, I found myself reflecting on how much of the Native American community's history is tied to the history of the buffalo, both past and present. As the buffalo were brought to extinction, so once were the Indigenous people. Today with buffalo returning, we also see Indigenous communities revitalizing cultures (Crosschild et al. 2021).

Why Does it Matter to Bring the Buffalo Back?

Community revitalization and the meaning of bison to many Native American communities and individuals is an important aspect of bison reintroduction. For me, the main focus of this research experience was to examine how both bison and Native American communities have shared history and how this history also reflects a common resilience. The shared ideal of resilience helps start conversations on a wider scale around how bison reintroduction can bring Native American communities together. Given our shared history, we can look at buffalo as a mirror for community, a mirror for a way of life. We relate deeply to the bison—not just because of shared history but because we share these livelihoods. We share survival; we share family. It is why when some refer to the bison, they say, "our bison cousins or relatives." It is a deeply connecting sentiment that ties bison reintroduction to reconnecting with our communities.

With my studies and the connection Native Americans have with bison in mind, I wanted to focus on how bison can help strengthen community health and wellness, with a focus on educating and uplifting Native American youth. Native Americans have a higher predisposition for chronic illnesses, such as heart disease and diabetes. There are also higher rates of substance abuse, which can lead to liver disease and accidental death. An attributed cause of these health disparities in Native American communities is the loss of connection to traditional ways of living, because much of Native American culture and lifestyle was lost through processes of colonization and assimilation (Ehrenpreis and Ehrenpreis 2022).

During my fieldwork, I had the chance to see community efforts to address these challenges in action while attending Browning's Iinnii Days (Iinnii means bison in Blackfeet). This is a community-led event meant to celebrate the bison and the culture of the Blackfeet people. This event included traditional games, a buffalo harvest, and community-building events. This was a good place to examine how traditional knowledge is being integrated back into the modern learning of Blackfeet youths. I was surprised to see kids of all ages attend the event, offering a good example of how cul-

tural revitalization as a value is front and center when considering the return of the bison. Cultural reconnection—with buffalo and with a sense of community—could be an important stepping stone for promoting a healthier way of living. Eating more traditional food and following more traditional ways of living could improve the health and wellness of the people. Introducing these ideals to younger generations is important because they are ultimately the future knowledge holders for the community. Kim Paul, the community leader who shared about her own educational journey during our drive along the mountain front, explained the importance of this reconnection with Blackfeet ways of knowing:

> So we've had this transition of thinking and a transition of knowledge to where we're coming back into that really beautiful knowledge, and [today] we're picking up and reclaiming pieces of that, all the time that was taken away.

As many work toward this revitalization of culture, it begs the question of what stands in the way. Seeing this idea of revitalization isn't just a simple idea; it's a powerful concept, and with power there can be challenges.

Challenges Facing Coexistence of the Bison

Many Native American communities are advocating for the return of the buffalo. An example of this is my own community, the Blackfeet Tribe of Montana, who have been working for decades to bring back the buffalo to the Blackfeet Nation. In the summer of 2023, the Tribe released a herd of 49 bison near Chief Mountain, a sacred area to the Blackfeet people. While this was a very powerful step, the release did not go entirely as planned, making it necessary to go back to the drawing board and come up with new ideas for a more permanent release. In this case, the bison tried to go back to the pastures in which they were raised; they were trying to go back home. How can we make these lands that were once their home, but now are unfamiliar, a place for the bison to call home again? With this first effort to reintroduce the buffalo, the Tribe learned valuable lessons: if a buffalo wants to go somewhere, it will go, no matter what stands in its way. This trait of stubbornness is often a double-edged sword, coming with resilience yet making it harder to find common ground for shared, innovative ideas. This highlighted that fitting buffalo into today's fragmented world is not always easy and requires creative thinking!

This is what makes some people hesitant about the idea of reintroducing the buffalo: having to consider community safety, potential consequences for livestock, and what we can do to make the bison comfortable. With this experience, I heard firsthand from Blackfeet livestock producers about the concerns and efforts of bison reintroduction. It was touching to hear the stories of people who live in the Blackfeet community just a road away from where I live. I learned that trust was the most brought up concern: trust in the local government and trust in the bison itself. Can we trust the bison will not harm the cattle or eat all the grass? Can we trust they will stay where we want them? Can we trust the local government to keep its promises to balance different community needs? These were some of the questions I asked myself when it came to conversations with some Blackfeet livestock producers. These producers are not only Blackfeet individuals with a deep connection to the culture, but they also must think of their livelihoods that rely on leased land owned by the Blackfeet Tribe (Shamon et al. 2022). A Blackfeet livestock producer we spoke to said:

> That's the part that is hard for me to explain: the buffalo are taking some of our lands, when instead we need to work together to find a happy place for both and to manage both in a positive direction because we need them both. I'd love to see them both flourish and be profitable.

I realize that I learned to sympathize more with both sides of the conversation, and that the closer you look at the problem, the more branches you see. I think this is a wicked problem with no clear solution, but that does not make it hopeless, nor does it mean the questions surrounding it are useless. The truth is that trust must be built, and trust must be felt by everyone for bison reintroduction to be seen as good for the whole community. At this moment, this is simply not yet true. A Blackfeet livestock producer we spoke to explained:

> "I'd like to see the buffalo feed more of our people [...] Are they really caring enough to feed our people? We're trying to build these packing facilities where they really could make a difference. We could feed our school children; we could feed our lower-income people [...] there should be a program where we can do the same [feed the people]. If we could ever get to that point, we would sincerely work together, not pull from each other. It would be a happy place."

This does not mean it is all conflict. When tough conversations come up, they can lead to even stronger, deeper connections and trust in the long run. It brings us back to the idea of stubbornness, seen not only in the bison but also in many communities, leading us to become stuck in a certain way of thinking that can foster a "Me vs. You" mindset. Learning to trust starts conversations, creates relationships, and begins a new era of collaborative thinking. It brings empathy for all views in turn, providing more thoughtful conversations, not just blind confidence of what people first think is right and wrong.

A Journey of Growth and Connections

One of the greatest lessons I learned was about perspective. From the conversations and personal stories I heard, I found that each and every person has their own way of looking at the world. Their unique experience was shaped by their life experience and connections to the animals and the people in the community. These connections are ultimately built on trust, which is why in conversations like these, trust is the most important resource. As we grow older and start to examine the world, we realize how every choice we make has an effect.

I want to bring us back on the drive with Blackfeet community member, Kim Paul. Kim is the co-director of Piikani Lodge, a community-led organization focused on supporting Blackfeet wellbeing. In this work, she takes pride in inspiring younger generations, not for recognition, but because she sees the spirit of all the people she talks to. She holds no malice, no judgments, and when she meets you for the first time, she welcomes anyone willing to learn. The day we saw the bobcat come out of the brush right next to us on the road was my first field day with the team on this project. It was my first time getting hands-on interview experience and having a voice in the conversation. During our first conversation about the project and the research experience, Dr. Madison Stevens told Zahara and I, "In this kind of research, we learn to not be a fly on the wall." When working with people in the community, you're not just listening to people, you're hearing their lives and participating in the conversation. During the drive with Kim Paul, she spoke about her journey and its challenges. Through this conversation, I learned it is important not to let those challenges hold you back. I learned to ask meaningful questions, questions that not only guide the research but my life as well.

Treffrey Deerfoot, a project advisor, stated, "That's my challenge to you as young people. Ask a lot of questions. You're in university—ask those good questions, 'cause that's going to give you guidance." I learned to look at research in a less biased way, recognizing that every opinion is important and every voice matters. I learned to think harder about my burning questions because they matter. Overall, this experience was not rooted in numbers or mountains of paperwork; it was rooted in conversation, shared knowledge, shared ideas, and a wide range of perspectives. An idea I once held as thought, "Simply bring the buffalo back," has grown into a tree of branching stories and ideas that I want to hold with me as I grow my career path and a new way of thinking.

Left to right: Jonni Spotted Eagle, Madison Stevens, Zahara Thompson Research Team group photo taken during field work in Browning, MT. Setting up a traditional ceremony to honor the Piikani Lodge land with Kim Paul, Treffrey Deerfoot, and Helen Augare Carlson.

Zahara Thompson, Jonni SpottedEagle, Treffrey Deerfoot Hilleman Scholars Zahara Thompson and Jonni SpottedEagle with Treffrey Deerfoot, Blackfoot Elder and project advisor.

About the Author

Jonni SpottedEagle is a sophomore at Montana State University majoring in Microbiology on a Pre-Med track. She is a proud Indigenous woman from Browing, which is located on the Blackfeet Reservation of Montana. She has worked with her faculty mentor, Dr. Madison Stevens, since Summer 2025 on Dr. Stevens's National Science Foundation funded "Restoring Human-Wildlife Coexistence in Working Landscapes" project. In Jonni's free time, she loves to read and spend time with family. In the future, she hopes to attend medical school, and is committed to become a health professional, for her hometown community and to make her family proud.

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Translating Birds: The Use of Birdsong in Contemporary Music

2025 - 2026

MSU Acoustic Composition

By Emmett Tyler Aschim II

Abstract

Inspired by the timeless tradition of composers who have found musical inspiration in birdsong, this project delves into the possibilities of transcription and transformation within the context of contemporary chamber music. My string quartet, Syrinx (2025), is a direct exploration of this practice, using the unique vocalizations of common birds found in the Bigfork, Montana, region—specifically the black-capped chickadee, American robin, crow, and blue jay. The work is structured into two contrasting movements to demonstrate the versatile compositional potential inherent in these natural sounds. The first movement, "Birdsong," is a lyrical and romantic exploration of direct transcriptions of these avian melodies. Unlike the purely imitative approaches of earlier composers, this movement integrates the inherent melodic and rhythmic contours of the birds' songs into a modern chamber music idiom. The fluting warbles of the robin and the characteristic fee-bee call of the chickadee are rendered with extended, romantic expressiveness, creating a soundscape that is both familiar and newly interpreted. This approach not only honors the source material but also reveals the complex musicality already present in the natural world. In stark contrast, the second movement, "Broken Wing", reconfigures the same core themes through the rigorous lens of serial technique. This movement transforms the previously lyrical birdsong into a fragmented, disoriented sound. The systematic reordering and manipulation of the transcribed pitches creates a sonic impression of a bird in distress—its song broken, its movements erratic. By using the same source material for both movements, Syrinx highlights the dramatic difference that compositional method can create, transforming the serene beauty of the first movement into the unsettling struggle of the second. This project goes beyond a simple musical exercise by situating Syrinx within the larger historical use of birdsong in music, citing pioneers like Olivier Messiaen and Einojuhani Rautavaara. Messiaen, for instance, saw birdsong as a sacred expression and developed a system to accurately notate it, while Rautavaara incorporated recordings of arctic birds directly into his orchestral work, *Cantus Arcticus*. My work adds to this lineage by drawing on contemporary biological research into the avian syrinx—the bird's specialized vocal organ. The syrinx's unique two-sided structure, which allows birds to produce two separate melodies simultaneously, offers a fascinating model for compositional methods. By treating birdsong as not only a subject but also a structural blueprint, this paper and the accompanying quartet demonstrate a path for contemporary composers to integrate natural phenomena into their practice in a deeply meaningful and innovative way.

Literature Review

The dialogue between biology and music in the study of birdsong is deep and complex. On the biological side, avian song is understood primarily as a product of the syrinx[1] . Research shows that its dual sound soures can produce intricate melodic interplay, occasionally generating two pitches at once. Composers from Olivier Messiaen[2] to Kaija Saariaho[3] find inspiration in these complexities, using transcription, imitation, and transformation to translate avian voices into hu-

1 The syrinx is the vocal organ of birds, located at the base of the trachea, capable of producing multiple pitches simultaneously.

2 Olivier Messiaen (1908–1992), French composer and organist, is especially known for integrating detailed birdsong transcriptions into works such as Catalogue d'oiseaux (1956– 1958), treating avian material as primary compositional structure rather than ornament.

3 Kaija Saariaho (1952–2023), Finnish composer associated with post-spectralism, in corporated birdsong-inspired timbral and gestural transformations in works such as Aile du songe (2001), where flute writing evokes avian contour and texture.

man contexts. Rautavaara's[4] *Cantus Arcticus* famously sets recordings of birds against orchestra. These precedents frame my work in Syrinx, where birdsong functions as primary thematic material, grounded in biology and flexible compositionally.

In addition to the broader international lineage of birdsong composition, regional works engaging species native to Montana provide important contextual grounding for this project. Paul Naylor's *Symphony No. 4: The Chickadee* Symphony centers explicitly on the black-capped chickadee, integrating avian motives into a symphonic framework that emphasizes environmental identity. Similarly, Philip Aaberg's "No Wonder They Sing" reflects an ecological awareness of northern Rocky Mountain birdlife, embedding regional soundscapes within an orchestral idiom. These works situate birdsong within large-scale programmatic and environmental narratives. By contrast, Syrinx [5] adopts a chamber setting and emphasizes direct transcription as compositional genesis, treating birdsong not only as representational material but as structural source. In this way, the project engages regional traditions while emphasizing methodological transformation as its core focus.

Research Methods

The material for Syrinx was generated entirely through transcription by ear. I listened repeatedly to birds native to Montana, translating their vocal gestures and interplay into traditional notation. This method was inherently subjective; my choices shaped rhythm, contour, and harmony, but the goal was true representation of natural sound. Through transcription, I preserved the distinct melodic, rhythmic, and timbral characteristics of each species, allowing their natural patterns to serve as collective foundational material.

In the first movement, "Birdsong", transcriptions are presented directly within a lyrical and extended tonal framework. Multiple birds appear simultaneously across the quartet, with melodic lines exchanged between instruments in a hocket-like fashion, creating the impression of dialogue. Harmonization emphasizes the intervals and expressive qualities of the natural calls, producing a flowing texture while maintaining each bird's unique voice.

The second movement, "Broken Wing", abstracts these melodic gestures through serial techniques. Intervallic content is reorganized into structured pitch sequences, while rhythms are fragmented and displaced, producing instability and distortion. Following an expressive narrative in which a bird collides with a window, previously lyrical material is rendered in a tense, fragmented, and expressionist idiom. Serial transformations show how transcription functions as both source and framework for structural and expressive exploration.

These methods demonstrate how attentive listening, transcription, and procedural transformation generate material that is biologically informed and narratively expressive, situating Syrinx at the intersection of ecological observation and compositional technique.

Findings

The compositional results of Syrinx reveal both continuity with and departure from prior traditions. Like Messiaen, I sought to preserve the unique rhythmic and melodic signatures of birdsong, capturing the irregularities, phrasing, and expressive nuances of each species. Rather than treating the avian source as exotic ornament, I used it as the foundation of the piece, allowing natural patterns to guide melodic development, harmonic choices, and structural pacing.

The romantic idiom of the first movement emphasizes the lyrical potential of these transcriptions, with interweaving lines creating contrapuntal textures and implying interaction between species. In contrast, the serialized abstraction in the second movement demonstrates the structural fragility of these gestures, fragmenting melodic material and displacing rhythmic and harmonic elements to generate tension. The metaphor of the broken wing arises not only from narrative intent but from an abstract sonic re-interpretation of a real event.

While the biology of the syrinx provided grounding for understanding complex avian sounds, the compositional act reframed those mechanisms within human practice. Translating natural vocal gestures into notated, performable music required negotiating fidelity to the source with formal design. Syrinx is therefore both a study in avian biology and a reflection on the possibilities of attentive listening and procedural manipulation to produce a unique formal approach.

Conclusion

By treating the syrinx as a biological model and birdsong as compositional material, Syrinx situates itself within a lineage that includes Messiaen and Rautavaara, while establishing a personal space rooted in Montana's soundscape. Centering native species within a chamber framework, Syrinx engages a localized acoustic ecology, positioning compositional practice as a form of environmental attentiveness. The project illustrates how attentive listening, systematic transcription, and procedural manipulation can produce material that is both biologically informed and musically coherent, reinforcing the compositional potential inherent in natural sound.

Beyond this work, the methods developed in Syrinx suggest pathways for future inquiry. Similar transcription-based approaches could explore interactions between more species of bird. Procedural transformation of biological source material also opens opportunities for interdisciplinary collaboration, bridging composition with bioacoustics, ecology, and performance studies. By framing birdsong as both subject and structure, composers can expand the boundaries of musical language while remaining grounded in the natural world.

In particular, subsequent work has extended these methods to guitar composition[6] . Overall, Syrinx exemplifies how interdisciplinary approaches can yield works that resonate across performance, research, and lived experience, highlighting the potential for ecological awareness and biological inquiry to coexist within contemporary composition. Future research in this area remains open-ended, as increasingly interdisciplinary approaches enable composers to explore and express birdsong in new and expanding ways.

About the Author

Emmett Aschim II is a senior at Montana State University majoring in Music, specializing in classical guitar and composition. A post-spectralist composer, he explores xenharmony, microtonality, and the translation of natural sounds into contemporary music. His work includes music for a variety of instrumentations and reflects diverse musical philosophies. Outside of the classroom, Emmett enjoys performing, experimenting with extended techniques, and studying new approaches to acoustic and spectral sound. He plans to attend graduate school to continue developing his compositional voice and research in contemporary and experimental music.

Resources and Recording of Syrinx (2026)

Birdsong: Two Movements for String Quartet

4 Einojuhani Rautavaara (1928–2016), Finnish composer, composed *Cantus Arcticus* (1972) for orchestra and recorded birds, subtitled "Concerto for Birds and Orchestra," integrating Arctic field recordings directly into the orchestral texture.

5 My subsequent project, Xenharmonic Praxes: Compositional Studies in 31-EDO for Guitar (Aschim II, 2025), applies

6 My undergraduate thesis, *Xenharmonic Praxes: Compositional Studies in 31-EDO for Guitar* (Aschim II, 2025), applies transcription-based methods that would help relate complex birdsongs to 31-EDO subsets.

1. Birdsong

For String Quartet

Emmett Aschim

Adagio

Violin 1
Violin 2
Viola
Violoncello

mp *mf* *mp*

9

Lento Agitato

Vln. 1
Vln. 2
Vla.
Vc.

f *mf* *mp* *subito* 7 *mf* *sim.* 7 *mp* *mf* 8 *p* < *mp*

13

Grave

Vln. 1
Vln. 2
Vla.
Vc.

8 *p* < *mp* *mf* *sim.* *p* *trippingly* *mp* < *mf* *f*

18

Lento

Vln. 1
Vln. 2
Vla.
Vc.

mp *p* *f*

26

Presto

Allegretto

Vln. 1
Vln. 2
Vla.
Vc.

mf *f*

33

Andante

Vln. 1
Vln. 2
Vla.
Vc.

mf *p* *mp*

40

(Andante)

Vln. 1
Vln. 2
Vla.
Vc.

46

Adagio

Moderato

p sempre legato

51

rit.

mp sim.

mf Cantabile

58

Allegretto

p subito

65

Largo

rit.

2. Broken Wing

For String Quartet

Emmett Aschim

Andante

Violin 1
Violin 2
Viola
Violoncello

mp

8

Vln. 1
Vln. 2
Vla.
Vc.

mf *p* *f risoluto*

16

Vln. 1
Vln. 2
Vla.
Vc.

mp *mf*

24

Vln. 1
Vln. 2
Vla.
Vc.

mf *f*

𝄋 **Scherzo**

pizz.

33

Vln. 1
Vln. 2
Vla.
Vc.

pizz.

mp *mf*

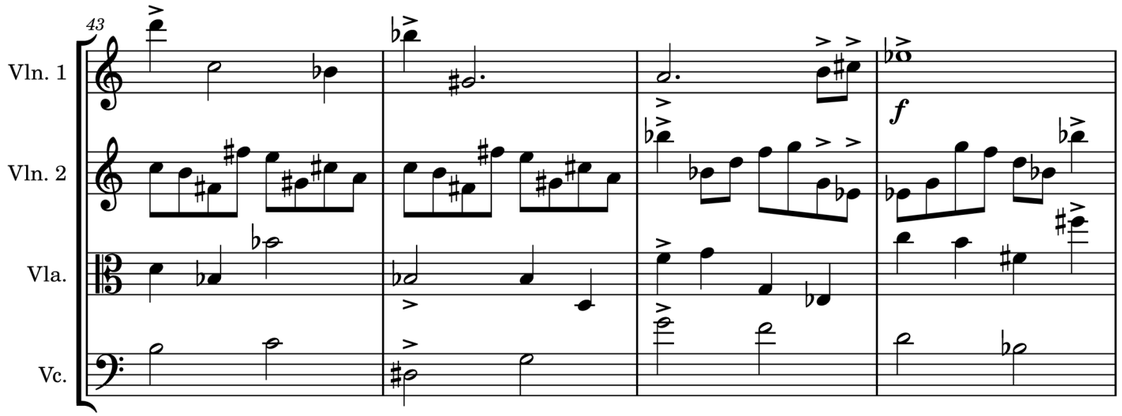
38

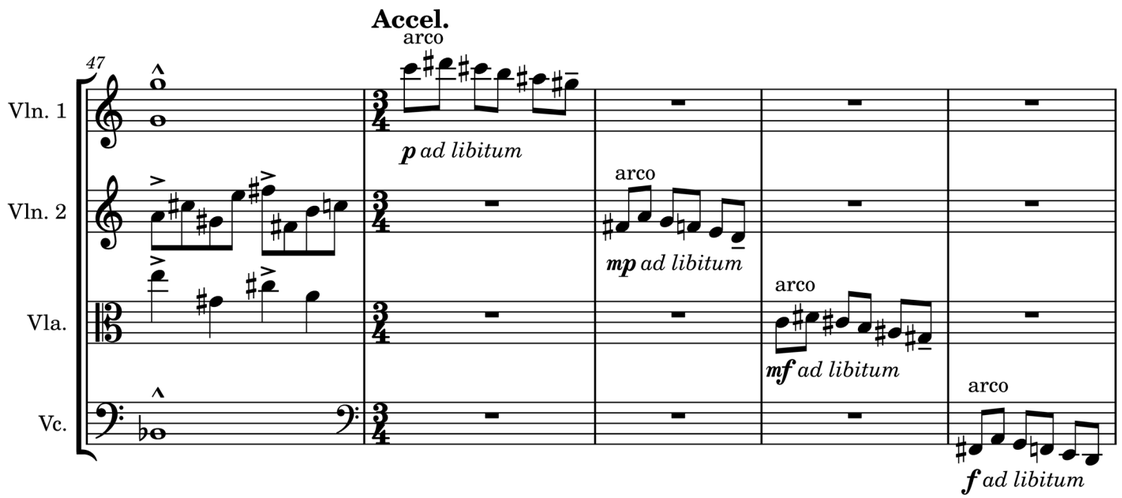
Vln. 1
Vln. 2
Vla.
Vc.

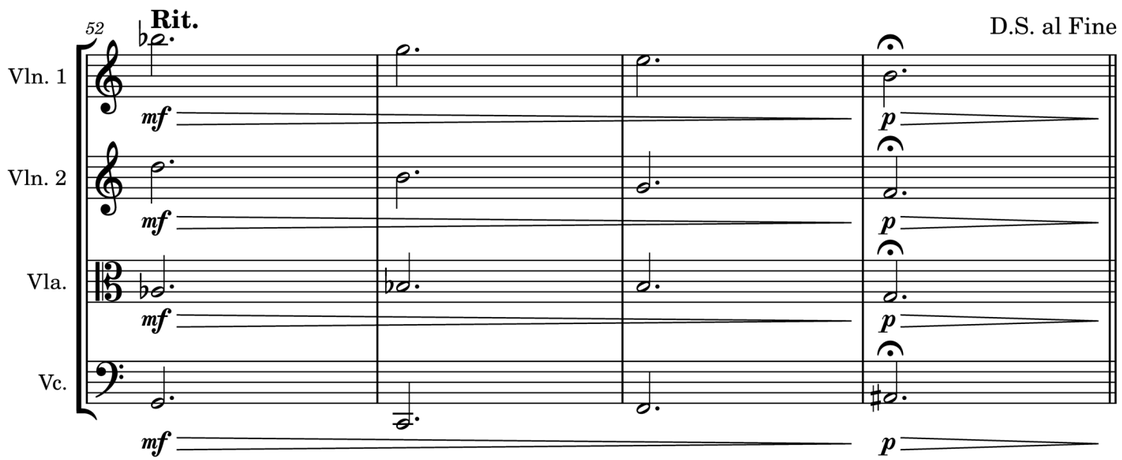
Fine

(pizz.)

mf risoluto *deciso*







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Modeling the Electromagnetic Structure of Deuteron Using Low Energy Nuclear Theory

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Abstract

Deuteron, the simplest possible nucleus consisting of a proton and neutron, is often used as a target in electro-scattering experiments, where a beam of electrons collides with a stationary deuteron sample. To calculate the interaction between the deuteron and electron, it is necessary to have a working model of the deuteron's nuclear potential and the resulting wave function. In cases where the internal substructure of the nucleons is negligible, such as with elastic scattering, a low energy theory may be used to describe the deuteron. In this regime, the nuclear interaction binding the proton and neutron contains One Pion Exchange potentials (V_OPE), the tensor operator ($\hat{S}_{12}$), and spin/isospin coupling terms. The goal of this project was to calculate the deuteron wave function and physical electromagnetic observables using this low-energy nuclear potential starting from the three-dimensional Schrodinger equation. This was accomplished using both analytical and computational methods. The matrix elements for the spin, isospin, and angular components were derived analytically using Wigner coefficients and angular momentum coupling techniques. The radial component matrix elements were solved computationally using Gaussian-Laguerre quadrature integration and matrix linear algebra. The resulting observables, including the ground-state binding energy (-2.2245 MeV), root mean square radius (1.908 fm), and magnetic moment (0.854 μN), all align with experimental measurements. These results indicate that the interaction potential and low-energy assumptions used are valid and model the deuteron accurately. Electron-deuteron elastic scattering experiments, such as those at Jefferson National Lab, could make use of this model to calculate the theoretical cross-sections to compare to their experimental data. The model could also be extended to experiments outside of Jefferson Lab to compute cross-sections for neutrino-deuteron elastic scattering.

The deuteron nucleus is made of a single proton and a neutron bound together and is the 2nd lightest nucleus beyond a single proton. We are motivated to study the binding interaction and resulting deuteron wave function as the first step in understanding more complex nuclei. Furthermore, understanding how the two constituent particles (the proton and neutron) bind together is necessary information in determining how other external particles interact with the deuteron as a whole. The simplest type of external interaction is

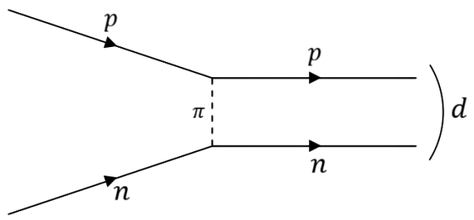

Figure 2: Feynman diagram of one pion exchange between a neutron and proton, forming a deuteron nucleus.

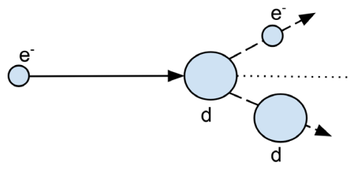

Figure 1: Electron-deuteron elastic scattering kinematics diagram.

elastic electro-scattering, where a beam of electrons is scattered off a stationary deuteron sample. Elastic scattering occurs when the total kinetic energy is conserved, and the internal structure of each particle (and thus its identity) is maintained, as shown in Fig. 1. Such interactions are frequently created at Jefferson Laboratory and other collider facilities. Thus, to predict how electrons will interact with the stationary deuteron targets in experimental settings, we must first model the deuteron and its wave function.

When modeling elastic scattering off a deuteron or a deuteron V_{OPE} by itself (with no external interaction), we can use a first-order interaction potential that does not consider the internal quark structure of the proton or neutron. In this low energy regime, the dominating interaction that holds the deuteron together is the One Pion Exchange Potential ($\hat{S}_{12}$), depicted in Fig. 2.($\hat{S}_{12}$), The full nuclear interaction potential as given by van Kolck1 reads,

$$\hat{V} = V_{CT}(r)\left(\frac{3+\ \sigma_1\cdot\sigma_2}{4}\right)\left(\frac{1-\ \tau_1\cdot\tau_2}{4}\right)\delta_{L,0} + \left(V_{OPE}^{(1)}(r)\hat{S}_{12} + V_{OPE}^{(2)}(r)\sigma_1 \cdot \sigma_2\right)(\tau_1\cdot\tau_2)$$

$$\hat{S}_{12} = 3(\sigma_1\cdot\hat{r})(\sigma_2\cdot\hat{r}) - \ \sigma_1\cdot\sigma_2$$

Where $\hat{\sigma}$ is the operator that acts on the spin and $\hat{\tau}$ is the operator that acts on isospin. From previous literature (Piarulli et al) we define the exact contact potential V_{CT} and one-pion-exchange potentials as follows:

$$V_{CT}(r) = \frac{C_S}{\pi^{\frac{3}{2}}R_S^3}e^{-\left(\frac{r}{R_S}\right)^2}$$

$$V_{OPE}^{(1)}(r) = \frac{g_A^2 m_\pi^3}{12\pi F_\pi^2}\frac{e^{-m_\pi r}}{m_\pi r}\left(1+\frac{3}{m_\pi r}+\frac{3}{(m_\pi r)^2}\right)C_{R_L}(r)$$

$$V_{OPE}^{(2)}(r) = \frac{g_A^2 m_\pi^3}{12\pi F_\pi^2}\frac{e^{-m_\pi r}}{m_\pi r}\ C_{R_L}(r)$$

where $R_S = 0.7$ fm and $C_S = -1.2565$ fm^2 is a constant fixed to reproduce the binding energy of the deuteron. R_S plays the role of a cut-off.

Additionally, to handle singularities at short distances (such as dividing by factors of r), a regularizing function is introduced to smooth the potential;

$$C_{R_L}(r) = 1 - \frac{1}{\left(\frac{r}{R_L}\right)^6 e^{\left(\frac{r-R_L}{a_L}\right)}+1}$$

is the regularizing function with $R_L = 1.0$fm and $a_L = \frac{R_L}{2}$. The other constants are the nucleon axial coupling $g_A = 1.29$, the pion decay constant $F_\pi = 184.80$ MeV and the mean mass of the pion $m_\pi = 138.04$ MeV.

The goal of this project is to model the deuteron using the described low energy interaction potential, and finding the ground-state wave function, binding energy, and other electromagnetic observables. Section 2A constructs the wavefunction. Section 2B solves the Schrödinger equation as far as possible using analytical methods. Section 2C computationally solves for the remaining components and calculates several physical observables of the deuteron. Finally, sections 3 and 4 present the final results and discuss their significance.

Methods

Constructing the Wave FunctionWe construct the deuteron wave function as the tensor product of the radial, angular, spin, and isospin components. Experimental results show that the deuteron has positive parity and a total angular momentum of $J = 1$, constraining the possible quantum numbers. The wave function then f_L the form shown below, with only the radial functions remaining unknown.

$$\psi_{1J_z}(r) = \sum_{L=0,2} f_L(r)[Y_L(\hat{r})\mathcal{X}_{S=1}]_{1J_z}\ \mathcal{X}_{\mathcal{T}=0,\mathcal{T}_z=0}$$

The equation above shows that the total wave function of the deuteron is the sum of the S and D waves, where the S wave has a total orbital angular momentum of 0 (L=0) and the D wave has a total orbital angular momentum of 2 (L=2). We know the angular, spin, and isospin components exactly: the Y_L's are the typical spherical harmonics, the X_S's are the coupled spins, and the X_T's are the coupled isospins given by,

$$\mathcal{X}_{SS_z} = [s_1 s_2]_{SS_z} = \sum_{s_{1z},s_{2z}} \langle 1/2\, s_{1z}\ 1/2\, s_{2z}|S\ S_z\rangle\ |1/2\, s_{1z}\rangle\ |1/2\, s_{2z}\rangle$$

and, analogously

$$\mathcal{X}_{\mathcal{T}\mathcal{T}_z} = [t_1 t_2]_{TT_z} = \sum_{t_{1z},t_{2z}} \langle 1/2\, t_{1z}\ 1/2\, t_{2z}|T\ T_z\rangle\ |1/2\, t_{1z}\rangle\ |1/2\, t_{2z}\rangle$$

where the first term in the summation is a Clebch-Gordan coefficient.

To solve for the unknown radial component of the wave function, we expand the f_L radial functions onto the 2nd order Laguerre polynomial basis ($L^{(2)}$) along with a normalization term and a negative exponential that accounts for the decay behavior of the nuclear interaction (i.e. the deuteron's wave function going to zero as the distance separating the two particles grows and the wave function going to zero as the two particles approach the same location). This leaves

the expansions coefficients ($\mathbf{c_l}$) as the only unknown parts of the wave function that must be solved within the Schrödinger eigenvalue equation.

$$f_L(r) = \sum_l c_l^L \, g_l(r)$$

$$g_l(r) = N_l L_l^{(2)}(\gamma r) e^{-\frac{\gamma r}{2}}$$

$$N_l = \gamma^{3/2} \sqrt{\frac{l!}{(l+2)!}}$$

Analytical Solution

To solve the 3D Schrödinger equation, we apply the variational principle to find the ground state wave function and energy by solving the associated eigenvalue equation.

$$\frac{\langle \Psi(r) | \hat{H} | \Psi(r) \rangle}{\langle \Psi(r) | \Psi(r) \rangle} \geq E_{ground}$$

In this way, we find the minimum ground state binding energy and the corresponding wave function expansion coefficients. Thus, it is necessary to find all of the Hamiltonian matrix elements, including the values contributed by both the kinetic and potential energy terms. Applying the nuclear potential to the wave function within the Hamiltonian matrix, we find non-zero matrix elements that can be computed analytically: pure spin/isospin elements and the tensor operator element.

$$\langle \mathcal{X}_\mathcal{T} \mid (\tau_1 \cdot \tau_2) \mid \mathcal{X}_\mathcal{T} \rangle$$

$$\langle \mathcal{X}_\mathcal{S} \mid (\sigma_1 \cdot \sigma_2) \mid \mathcal{X}_\mathcal{S} \rangle$$

$$\langle [Y_L(\hat{r}) \mathcal{X}_\mathcal{S}] \mid \hat{S}_{12} \mid [Y_L(\hat{r}) \mathcal{X}_\mathcal{S}] \rangle$$

To solve these elements, we expand and rearrange the spinors, spherical harmonics, and operators using Clebsch-Gordan and Wigner coefficients (expansion coefficients used in the coupling of 2+ angular momenta). Given states of definite spin and orbital angular momentum, these terms reduce to constants and coefficients in the remaining radial equation.

Once all three spin, isospin, and tensor operator matrix elements are calculated, their values can be plugged back into the Hamiltonian matrix. If we explicitly expand the wave function, we are left with the following radial functions. These are coupled differential equations as they both contain the f_0 and f_2 terms.

$$E f_0(r) = -\frac{1}{2\mu}\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial f_0(r)}{\partial r}\right) + V_{00}(r) f_0(r) + V_{02}(r) f_2(r)$$

$$E f_2(r) = -\frac{1}{2\mu}\left(\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial f_2(r)}{\partial r}\right) + \frac{6}{r^2} f_2(r)\right) + V_{20}(r) f_0(r) + V_{22}(r) f_2(r)$$

where

$$V_{00}(r) = V_{CT}(r) - 3V_{OPE}^{(2)}(r)$$

$$V_{20}(r) = V_{02}(r) = -6\sqrt{2} V_{OPE}^{(1)}(r)$$

$$V_{22}(r) = 6V_{OPE}^{(1)}(r) - 3V_{OPE}^{(2)}(r)$$

Computational Methods

The remaining matrix elements to compute are the $\mathbf{f_L}$ radial components.

$$\langle f_L(r) \mid \hat{T} + \hat{V} \mid f_L(r) \rangle$$

The potential energy components cannot be solved exactly, so we utilize the computational Gaussian-Laguerre quadrature integration technique. This method is similar to traditional trapezoidal Riemann sums but utilizes non-uniform intervals that are calculated and weighted to fit the Laguerre polynomials found within the integrand. Thus, the potential matrix elements' spatial integrals are computed directly, where $\boldsymbol{\omega}_\mathbf{i}$ and $\mathbf{x_i}$ are the Gauss-Laguerre weights and points respectively.

$$\langle \nabla^{L',L} \rangle_{l',l} = \frac{N_{l'} N_l}{\gamma^3} \int_0^\infty dx \; x^2 e^{-x} L_{l'}^{(2)}(x) V_{L',L}(x/\gamma) L_l^{(2)}(x)$$

$$\simeq \frac{N_{l'} N_l}{\gamma^3} \sum_{i=1}^{N} \omega_i L_{l'}^{(2)}(x_i) V_{L',L}(x_i/\gamma) L_l^{(2)}(x_i)$$

Using the kinetic energy operator in spherical coordinates and performing the integral numerically, we find the kinetic energy components

$$\hat{T} = -\frac{1}{2\mu}\left(\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial}{\partial r}\right) + \frac{\hat{l}^2}{r^2}\right)$$

$$\langle \hat{T}^L \rangle_{l',l} = \frac{\hbar^2 \gamma^2}{2\mu}\left[(l + L(L+1)) I_{l',l}^{(2)} + (l+1) I_{l',l}^{(1)} - \sqrt{l(l+2)} I_{l',l-1}^{(2)} - \frac{1}{4}\delta_{l,l'}\right]$$

where $\mathrm{I}^{(1)}$ and $\mathrm{I}^{(2)}$ can be solved in terms of only l and l'

$$I_{l',l}^{(1)} = \frac{1}{2}\sqrt{\frac{(l+1)(l+2)}{(l'+1)(l'+2)}} \quad for \quad l \leq l'$$

$$I_{l',l}^{(2)} = \frac{1}{2}\sqrt{\frac{(l+1)(l+2)}{(l'+1)(l'+2)}}\left((l'+1) - \frac{l}{3}\right) \quad for \quad l \leq l'$$

Choosing to use the first 40 terms in the $\mathbf{f_L}$ expansion, our Hamiltonian becomes an 80x80 matrix after solving for these radial matrix elements. Once the Hamiltonian matrix is found, it can be plugged into the eigenvalue $\mathbf{c_l}$ the coefficients and energy.

Of interest is the Hamiltonian matrix itself, as shown in Fig. 3. The kinetic energy components have no cross-terms and are strongest in the D-wave (f). Similarly, the pure spin/isospin components also lack cross-terms but are strongest in the S-wave (f_0) where they contribute a large attractive (negative) potential. Most interesting is the tensor components, which do have cross-terms, meaning there is interference happening between the S and D waves. This occurs due to the non-symmetric nature of the tensor operator as it couples the particles' spin and angular components. This tensor operator contributes additional attractive interactions between the proton and neutron and gives the deuteron some of its defining characteristics.

In addition to finding the Hamiltonian matrix, we can use the same Gauss-Laguerre quadrature integration to find various physical observables. In this particular study, we calculate the deuteron root-mean-square matter radius and the deuteron magnetic moment, given by the following operators:

- The rms matter radius where i is the index of the particle

$$\hat{\mathrm{r}}^2 = \frac{1}{2}\sum_{i=1,2} r_i^2$$

- The magnetic moment

$$\hat{\mu}_z = \sum_{i=1,2}\left(\frac{1+\tau_z^i}{2}\right)\hat{L}_z^i + \sum_{i=1,2}\left[\mu_p\left(\frac{1+\tau_z^i}{2}\right) + \mu_n\left(\frac{1-\tau_z^i}{2}\right)\right]\sigma_z^i$$

Once the full wave function is known (having solved for the remaining $\mathbf{c_l}$ coefficients via the eigenvalue equation), Monte Carlo integration can be used as an alternative numerical method to calculate more complex operators. In this technique, the integral is approximated by the wave function's probability distribution, and the operator is calculated directly on the de-coupled neutron and proton particles.

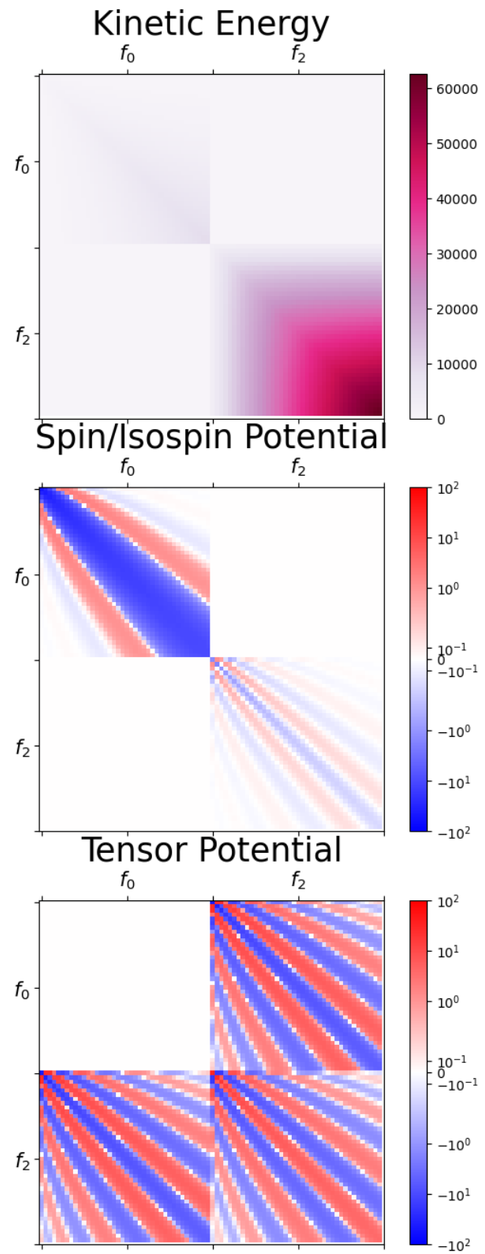

Figure 3: Full Hamiltonian matrix elements split into kinetic, pure spin/isospin, and tensor operator components, with f_0 and f_2 interaction terms on the off-diagonal quadrants and negative (blue) attractive potentials.

$$\langle \hat{O} \rangle = \frac{\langle \psi \mid \hat{O} \mid \psi \rangle}{\langle \psi | \psi \rangle} = \sum_{R_i \in P(r_1^i, r_2^i)} \frac{\psi_i^\dagger \hat{O} \psi_i}{|\psi_i|^2}$$

In this study, we use Monte Carlo integration to calculate the root-mean-squared matter radius as given previously. As this method relies on having a representative random sample, there is inherent √N error within the values measured. However, this error is inversely proportional to N where is the total sample size. Thus, it is important to use a large sample size (over 100,000 points) to produce a reasonable answer. This can be seen in Fig. 4 as the error bars decrease in size when the total sample size gets larger. Our final results are calculated using a total sample size of 300,000.

Results

From our analytic and computational solutions, we find the radial function expansion coefficients (c_1) and thus the radial functions themselves. A spatial plot of the f_0 and f_2 functions is shown in Fig. 5 as a function of relative distance between the two particles in the nucleus. Integrating over both waves, we find that the S-wave accounts for about 95.4% and the D-wave 4.6% of the deuteron ground state wave function. Both radial components approach zero at large and small r values, as expected from our construction of the expansion basis

Another set of results are the numerical values calculated for the deuteron binding energy, rms radius, and magnetic moment observables. The exact values are listed in Table 1. Additionally, experimental values are provided as a comparison to our theoretically derived numbers (Van Der Leun and Alderliesten, Mustafa, and Kellogg et al).

Table 1: Electromagnetic Observables

	Exact Numerical	Monte Carlo Numerical	Experimental
Binding Energy	$-2.2245\ MeV$	–	$-2.2246\ MeV$
RMS Matter Radius	$1.908\ fm$	$1.896 \pm 0.009\ fm$	$1.95\ fm$
Magnetic Moment	$0.8450\ \mu N$	–	$0.8574\ \mu N$

Finally, in order to ensure our Gauss-Laguerre quadrature integration is providing a stable answer, we perform the integration repeatedly, as shown in Fig. 6, while varying the algorithm parameters:

- M: The number of Laguerre Polynomials to include in the f_1 expansion. Our final results were calculated using M = 40.
- N: The number of integration points in the quadrature integration. Our final results were calculated using N = 100.
- y: A parameter that controls the integration grid size when converting between integration points (x's) and physical distances (r's). Our final results are calculated using y = 4.0.

Discussion

Fig. 6 illustrates that the chosen algorithm parameters fall within the stable regions, where the calculated deuteron binding energy is not diverging. Thus, it is assumed that the numerical Gauss-Laguerre quadrature integration is accurate.

Additionally, we have strong agreement within 1 percent between the theoretically calculated and experimentally found observable values. As they match closely, we can conclude the low energy model used to derive the results is an accurate representation of the ground state deuteron nucleus.

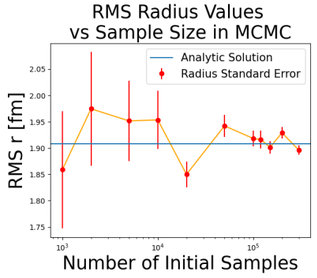

Figure 4: Root-mean-squared matter radius values for varying sample sizes in Markov Chain Monte Carlo integration, showing the reduction in error as sample size grows.

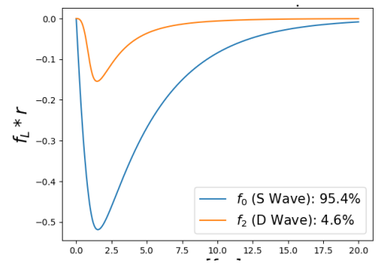

Figure 5: The radial wave function components with c_L coefficients solved as a function of distance. Both the S (L=0) and D (L=2) waves are negative (attractive) at close range and go to zero at large r values.

A further conclusion is that the first order interaction potential defined at the start of this paper is valid under the low energy assumptions (where the proton/neutron internal structures are negligible).

The next steps for this project are to calculate more observables using the Monte Carlo integration, including electron-deuteron elastic scattering form factors and cross sections. These values could then be compared to Jefferson Laboratory scattering data, further constraining the theoretical model.

About the Author

Sarah Heller is a senior at Montana State University majoring in Physics and Mathematics, with a minor in data science. During the summer of 2025, she conducted theoretical nuclear physics research at the Thomas Jefferson National Accelerator Facility in Virginia. Sarah plans to pursue a PhD in particle physics, studying neutrinos or high energy collider physics. She has served as an officer of the Society of Physics Students club and worked as a tutor at the Math and Stat Center since 2022. Outside of academics, Sarah enjoys dancing, reading science fiction, and drinking tea.

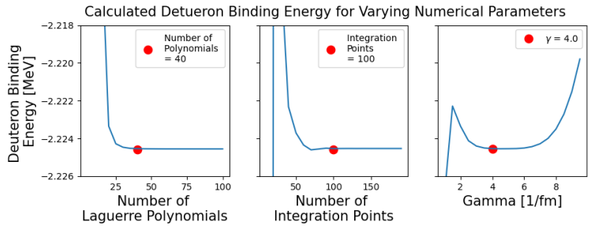

Figure 6: To validate the Gaussian-Laguerre quadrature integration, we vary the numerical parameters and plot the calculated ground-state energy to show they produce a stable value.

Acknowledgements

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The Shape of Uncertainty

Concept, Thought Process, and Connection to Quantum

By Jack Schnepf

Abstract

"The Shape of Uncertainty" is a painting created through my collaboration with QCORE, Montana State University's quantum computing research initiative. The work bridges the languages of art and science, exploring how painting can visualize the principles of quantum computing, such as superposition, entanglement, and the role of observation in shaping reality. Through this painting, I seek to demystify quantum mechanics by showing how these principles exist not only in abstract theory but also in life's everyday experiences, inviting viewers to encounter unseen structures of reality through light, movement, and perception. My artistic practice has long been centered on translation, creating paintings that communicate complex human experience in simple ways that connect to the soul. My work is guided by a goal of inspiring empathy and deepening understanding of ourselves and the world around us. Through a personal lens, I explore emotional and psychological complexity, reflecting on memory, healing, vulnerability, empowerment, and the space between consciousness and the physical world. Over time, this process has evolved into diving into the unknown, whether through a new medium or idea, and discovering clarity through creation itself. "The Shape of Uncertainty" extends this pursuit into the scientific realm. The painting emerged from conversations with physicists, leadership, and researchers at QCORE, exploring how art can contribute to scientific discovery and research translation. Quantum mechanics reveals a world where observation alters outcome, where particles exist in multiple states simultaneously, and where uncertainty is foundational rather than a flaw. These ideas took form through imagery grounded in Montana. The horse, a familiar symbol of the West, became a way to translate quantum principles into something tangible. When running together, horses appear as a single wave, yet up close their individuality becomes clear, much like how light behaves as both a wave and a particle. In their power, the horses reflect quantum computing itself: an immense, untamed force shaped by human ingenuity, just as humans domesticated the wild horse. Points of detail anchor the viewer, while areas of abstraction leave room for reflection and discovery. Through three-dimensional forms and translucent layers of paint, the work resists a single interpretation, embodying the essence of quantum behavior and giving shape to uncertainty. Visitors were invited to add their own small chalk marks representing particles of light above the horses' heads, mirroring quantum uncertainty and measurement. Each mark was placed intuitively, appearing as chaos at first, yet over time, patterns began to emerge, reflecting how statistical order arises from randomness in quantum systems. Visitors unknowingly entangled themselves with each other through shared participation in the living, expanding system that the painting embodies. Ultimately, the painting invites viewers to experience quantum not as an abstract or complex theory, but as a metaphor for how we perceive, connect, and find meaning within the unknown.

Broken Down Connections to Quantum: The Title and Core Concept:

The title, "The Shape of Uncertainty," is a paradox that grounds this piece. It proposes that the formless and probabilistic nature of the quantum world can be given tangible shape through art. The painting uses the familiar subject of running horses to explore fundamental concepts of quantum computing, creating a bridge for viewers between a classical image and a quantum idea.

Superposition: The Horse in All Possible Strides

A running horse, especially at full gallop, exists classically in a single position at any given instant. However, in a quantum sense, this painting suggests it exists in all possible positions simultaneously until it is observed. The blurred, overlapping forms are not just motion blur; they represent the horse existing in a multitude of potential states. With close examination, the viewer can find the more detailed "measured state" of the main horse with the textural waves of Venetian plaster subtly showing a ripple of possibility leading to this moment of collapse.

Uncertainty & Measurement: The Observer's Effect

The hazy, abstracted areas of the painting convey the inherent uncertainty in quantum mechanics. A quantum system remains undefined until it is measured, a process I've tried to embody in this piece. Viewers are invited to thoughtfully examine the work, particularly the main horse's face and eye. In this moment of focused observation, the form becomes more defined and "measured." The shiny and textural charcoal particles floating within the undefined horses can be seen as individual quantum particles in a probabilistic cloud, awaiting a quantum event" to be observed and defined.

Entanglement: The Linked Herd

While the painting has a central focus, the presence of multiple horses allows for a conversation about entanglement. Much like a herd of horses running in perfect unison—their movements so coordinated, they seem connected beyond simple proximity—the forms in this painting are interconnected. The central horse is subtly intertwined with the other forms through overlapping shapes, implied forms through color shifts and "ghost" entangled limbs. Fine applications of charcoal and plaster subtly connect these forms, symbolizing a shared destiny that transcends physical distance.

Wave-Particle Duality: The Flow and the Form

Running horses create a dynamic "wave" of motion and energy, but they are also distinct "particles" (individual horses). My uses of Venetian plaster as a textural wave and shiny charcoal as individual particles further support this idea. Just as light can behave as both a wave and a particle, these running horses embody both a continuous flow of energy and distinct, resolved forms, offering a visual parallel to quantum duality.

The Quantum Promise

Horses have long symbolized speed, power, and freedom. Quantum computing similarly promises to unlock unprecedented computational power and solve problems previously thought impossible. The energy and dynamic motion of these horses reflect that profound leap in capability; much like a horse can navigate complex terrain with incredible agility, quantum computers are designed to navigate vast, complex problems that classical systems cannot.

Visitor-Placed Particles: A Living System

The painting is an open-ended system. During the process of creating this piece, visitors were invited to add their own "particles"—small dots of paint—in a designated place, following minimal instructions. This act introduced a participatory layer that directly mirrored quantum uncertainty and measurement. Each particle was placed intuitively, appearing at first as chaos. Yet over time, patterns emerged from the accumulation, reflecting how statistical order arises from randomness in quantum systems. In this process, visitors unknowingly entangled themselves with each other through shared authorship. Their presence and participation were not supplementary—they were essential to completing the living, expanding system the painting embodied.

About the Author

Jack Schnepf is a recent graduate (Fall 2025) of Montana State University, where he earned a BFA in Studio Art with a focus on drawing and painting. He has worked with QCORE, MSU's Quantum Collaborative Research and Education initiative, as Executive Administrator and Artist-in-Residence, where he used painting to help demystify quantum mechanics through visual translation. His work explores art–science collaboration, consciousness, personal introspection, and nature, creating artwork that inspires empathy and a deeper understanding of ourselves and the world around us. Through this practice, Schnepf seeks to repair a fractured world by targeting the sources of its unrest.

Artwork by Jack Schnepf

Cloudy Most Days

By Brynn Engler

cloudy most days

in the beginning, you mapped out the end
how you would cry
how you would leave
in rage and anguish
ripping at the collar of your shirt
clawing at invisible cuffs bound to your wrists and ankles

it is cloudy most days
and you are
walking backward on a bike path
away from me
so small underneath the branches of the
speckled cottonwood trees

and i feel like

i feel like
i have soaked in a bath of the ones who have drained your heart
i have drunk bitter coffee with your enemies and lovers alike
i have smelled their sweat and licked their salty palms
and i have not hurt them because, at one point, they loved you

it is cloudy, so i put my coat

on
and
off

on
and
off

at one time
i would reach for you
when i was cold

now the frigid air stings my hands
and i wonder why you don't want to touch me anymore,
when just months ago, you tried to crawl underneath my skin

even, today
in the rain

i'd let you lie there
in hopes to warm you up

Artist Statement

This poem reflects on strange and shifting weather as a lens for navigating love in one's twenties. Rather than offering a fixed resolution, I hope this poem invites readers to sit with ambiguity and draw their own conclusion, allowing personal experience to shape its meaning.

About the Author

Brynn Engler is a sophomore at Montana State University studying Environmental Horticulture with a focus in Landscape Design and a minor in English Writing. Brynn owns her own business and spends much of her time building, exploring, and maintaining natural spaces. Born and raised in Bozeman, Montana, her work is deeply influenced by the landscapes around her. She writes poetry inspired by travel, love, and life's quieter moments—her pieces often carrying a sense of melancholy and honest, unfiltered expression.

Is Absolute Pitch Used Outside of Music?

By Tyler Flock

Abstract

This persuasive essay explores the concept of Absolute (Perfect) Pitch (AP), the rare ability to identify and produce a particular pitch without a reference pitch. While typically associated with music, research suggests AP may have evolved from speech, with environmental and genetic factors contributing to its development. This piece asks the question "Is absolute pitch used outside of music?" by referencing and summarizing peer-reviewed sources by well-regarded experts to formulate opinions. The theory of AP evolving from speech is supported by studies on native speakers of tonal languages, who exhibit a higher percentage of AP users and show connections between AP and enlarged temporal lobes involved in speech processing. It highlights research that suggests that non-AP users also employ an implicit form of AP for tasks involving the perception of pitch class and height. Results from multiple studies imply that absolute pitch is indeed used outside of music and mostly aids in the perception and interpretation of daily conversation, although its full scope remains a scientific mystery.

Absolute Pitch (perfect pitch) as we know is the rare ability to name or produce a note of a particular pitch in the absence of a reference pitch. In her article, "The Puzzle of Absolute Pitch," Diana Deutsch states that the Absolute Pitch (AP) ability is estimated to occur in fewer than 1 out of every 10,000 people in our population. To develop AP, research shows that there are environmental and genetic components involved. Typically, the only context where one would hear AP being discussed is in a musical environment, as it is not nearly as well-known as it could be. But after all, the ability only really seems both feasible and useful to a tiny population of musicians, right? According to Deutsch, AP is theorized to be an evolved feature of speech. It has even been argued that "AP is one of the cleanest examples of a human cognitive ability that arises from the interaction of genetic factors and environmental input during development" (Zatorre 2003, quoted in Moulton 2014, 517). These two statements open the gateway to the possibility of AP being useful to everyone and having more uses outside of just music, such as helping us as humans interpret the different meanings in our conversations.

Seeing that an understanding of the AP ability has been established, it is now possible to explore the more complex components and present the two different types of AP: active, assigning an auditory pitch to a given pitch name, and passive, assigning a pitch name to a given auditory pitch (Dohn, et al. 2014, 359). Research taken from Deutsch's article supports the idea that as non-AP users, we also use an implicit form of AP (not like the one tonal language speakers use) to do different tasks. (A tonal language is one where the same word or phrase can have two different meanings based on the tone and pitch when speaking it.) Research by Terhardt and Seewann (1983, 2), as paraphrased by Deutsch (2002), found that "musicians who lacked absolute pitch were nevertheless able to judge to some extent whether or not a passage was played in the correct key" (202). Deutsch also observed that when making judgments of the tritone paradox (an auditory illusion where a set of notes is played in sequential order and is heard in either ascending or descending order by different people), most people will either place tones in a certain region of the pitch-class circle as higher and vice versa for the lower region. "Listeners' judgments reflect a systematic relationship between pitch class and perceived height" (Deutsch 2002, 202), meaning that when making these judgments, we are using an implicit form of AP.

Next come the two main components of AP: "(a) long-term pitch memory, which is widespread, and (b) the ability to label pitches" (Levitin 1994, 415), similar to the labels active and passive (Dohn et al. 2014, 359). Now, what do researchers say are the general origins of the AP ability? As previously stated, Deutsch theorizes that AP is an evolved feature of speech. She supports this claim by presenting her research on native speakers of tonal languages, such as Vietnamese and Mandarin, and their high percentage of AP users. "According to this line of reasoning, the potential for acquiring absolute pitch is universal at birth and can be realized by giving the infant the opportunity to associate pitches with verbal labels during the first year or so of life" (Deutsch 2002, 200). Later in the same article, Deutsch goes on to connect AP users and the commonly seen enlargement of the temporal lobe, which is involved in speech processing. The idea of a connection between AP users and enlarged temporal lobes plays a significant role in the theory of AP evolving from speech.

On the surface, AP seems to have little fundamental value to humans until one looks deeper into the similar brain mechanisms between the AP ability and speech. It is thought that AP was once an early speech tool that evolved into the musical trait it is now. Research shows that we are not the only species to have the AP ability. Both Deutsch and Moulton argue that songbirds also have AP and use it to communicate with one another. Parncutt and Levitin (2001) also acknowledge research supporting the idea that not only songbirds, but wolves, and monkeys also demonstrate AP memory. In some cultures, humans also use an implicit form of this ability to communicate. Evidence of that claim is shown in research by Deutsch on native speakers of tonal languages, such as Vietnamese and Mandarin, demonstrating how close in pitch a random group of speakers say the same phrase. Unsurprisingly, those two cultures wield some of the highest percentages of AP users in the world. Often, these speakers utilize long-term pitch memorization in the same way an AP user (not from a tonal language culture) would when recalling notes. Both are associating a pitch with a verbal label. From an evolutionary perspective, it makes sense that this ability is still genetically present in some animals as well as in humans, where it is used daily to communicate in some of our oldest cultures.

One might argue that just because there are a few articles on the AP ability evolving from speech, or because it may be used for minor tasks in our day-to-day lives, this does not demonstrate that it is useful for everyone. The "minor tasks" are music related anyway, so how is it useful to non-musicians? Because of the genetic component involved in the development of AP, only certain people have the ability. Regardless, research was still performed on all types of people, not just the musically inclined. With the evidence highlighted in this essay, it is safe to infer that although AP for music can only be acquired for a small percentage of lifelong musicians, there are other uses of the ability that can be developed, with one of the most prominent theories being that the AP ability helps humans interpret different meanings in conversation.

While new findings about AP continue to emerge, many aspects of the ability remain mysterious. This essay explored the question, "Is absolute pitch used outside of music?" through analysis of peer-reviewed studies. Research suggests that the answer is yes, based on the theory that AP is an evolved speech tool, evidenced by tonal-language speakers, and by its daily use to aid in the interaction and communication of animals like mockingbirds. Additionally, individuals without the AP ability may also demonstrate an implicit form of the ability to make perceptions of pitch class and height. Although current research is still limited, these findings suggest that whether we are aware or not, different forms of AP can be used to communicate in our day-to-day lives—with or without music involved.

About the Author

Tyler Flock is a junior at Montana State University majoring in Music Education. He sings with multiple MSU Choirs, sings/conducts for a few in the Bozeman community, and plays the alto saxophone in the Spirit of the West Marching Band. When he is not performing, Tyler enjoys spending time with friends and family, playing pickleball, and exploring new places. In the future, Tyler hopes to obtain a doctorate in choral conducting and share his love for music at the collegiate level.

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Effects of Unpredictable Precipitation Patterns on Adoption of Sustainable Agriculture Practices in North Dakota

By Alyssa Harmel

Abstract

Anthropogenic impact on climate in today's world has resulted in increased precipitation variability, or irregularity, in the Northern Great Plains (NGP). This variability is expected to be seen as irregular timing of precipitation events, as well as an increase in frequency of extreme precipitation events. These irregularities have contributed to problems for crop production timing, as well as drought impact. In response to this variable climate, producers may need to utilize or develop strategies for maintaining yield. Assessment of producer insight on mitigation strategies for maximizing water usage could be integral to begin addressing the impact that variable precipitation is having on production and producers.

Challenges of Changes in Climate

Rises in global carbon dioxide levels are contributing to increases in temperature and precipitation variability in the Northern Great Plains (NGP) region. Precipitation variability includes unpredictability of both frequency and intensity of precipitation events. Locally, this will impact the agricultural integrity, or long-term sustainability of agriculture practices, of the NGP region. The NGP has seen an average temperature increase of 1.7 F° over the past few decades, greater than that of any other region in the U.S., as well as an increase in severe heat events. In addition, precipitation patterns in the NGP have shifted in favor of increasing precipitation amounts in spring and fall and decreasing amounts in the winter months. Extreme precipitation event frequency has also increased, resulting in higher amounts of precipitation in shorter periods of time, which does not always favor an increase in effective precipitation.[1] These irregularities in precipitation timing in the region have a large influence on agricultural productivity, and in combination with global and regional influences on crop prices, make agriculture in the region environmentally and economically vulnerable.

For this review, I will consider precipitation variability in North Dakota (ND). ND receives greater precipitation amounts than its western neighbor, Montana, but still experiences moisture differences across the state. Precipitation in North Dakota is expected to continue to increase during colder spring and fall months, aligning with predictions for the NGP region. This has potential to increase soil moisture but would delay the crop planting season and potentially impact harvest timing. This predicted precipitation increase during colder months is also thought to result in greater drought intensities for the state, because rising temperature rates could influence an increase in evaporation of colder-season precipitation.[2] In response, North Dakota crop producers have begun to utilize mitigative approaches to maintain yield and minimize potential soil health impacts in a time of irregular precipitation and greater drought risk.

Based on these considerations, the question driving this review is: How do unpredictable precipitation patterns affect the adoption of sustainable agriculture practices in North Dakota? The goal of this review is to assess North Dakota producer insight of strategies for maximizing water usage in a time of unpredictable precipitation variability.

ND Ecoregion Agriculture

The NGP region consists of multiple ecoregions, or subdivided areas with similar climate, geology, topography, and soil characteristics. North Dakota falls into four NGP ecoregions: the Northwestern Great Plains (ecoregion 43), Northwestern Glaciated Plains (ecoregion 42), Northern Glaciated Plains (ecoregion 46), and the Lake Agassiz Plain (ecoregion 48) (Fig. 1). In the Northwestern Great Plains ecoregion that comprises the southwest corner of the state, crop agriculture is not as prevalent because of poor soil quality and greater differences in water availability throughout the seasons. The Northwestern and Northern Glaciated Plains ecoregions that make up central North Dakota, as well as the Lake Agassiz Plain that includes the eastern border, are dominated by crop production be-

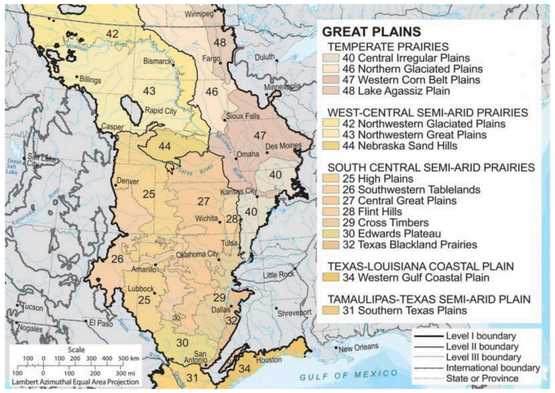

Figure 1: Level II and III ecoregions of the Great Plains partitioned by differences in climate, geology, topography, and soil characteristics. Reproduced from "Ecoregions of the Conterminous United States: Evolution of a Hierarchical Spatial Framework," by J.M. Omernik and G.E. Griffith, 2014, Environmental Management 54, p. 1254.

cause of increasing water availability as you advance east.[7] Water availability is integral to sustaining crop production in North Dakota, but with current and projected irregularities, cropland within the state is anticipated to become even more susceptible to drought than it already is.

To better understand production pressures that are associated with increasing precipitation irregularity patterns in North Dakota, I consulted Kipp Harmel, a crop producer from Rugby, ND. Harmel gave producer insight for the 2025 growing and harvest season in north-central North Dakota, as well as for observations of water use efficiency strategies applied in the area. His observations of the 2025 season and the strategies that have come along with the season's variability serve as recognition for each producer's crop rather than an average, as well as the hard work put into each yield.

Over the past year, Harmel experienced agricultural burnout related to the overwhelming lifestyle and unpredictability that comes with crop production.[8] This makes Harmel's observations and feedback not only important to this review, but for his own motivations for the future of his farming practice. In relation to this review, this experience should not be seen as a struggle, but rather as landowner authenticity behind how critical water use efficiency strategies are becoming for ND producers with increasing changes in precipitation timing. This also gives way to the notion that support for producers from both the scientific community and government infrastructure are necessary with increases in precipitation variability.

When asked, "What did this past growing/harvest season look like in central ND in relation to weather impacts?" Harmel had observational insight that aligned with current climate predictions of precipitation variability for the state. As previously mentioned, precipitation drives not only yield but also crop production timing. Over this past crop production season, April-September, central North Dakota producers experienced a later planting season and harvest season because of irregular precipitation event timing as well as immense weed pressure. Many producers could not plant wheat until late spring for the 2025 crop season due to high precipitation frequency during the normal planting timeframe. Once the crop emerged, later than usual, many producers integrated pesticide applications. Subsequent to application, rain fell yet again, resulting in pesticide removal and weed pressure. Heat and dryness increased throughout the summer, resulting in reduced crop productivity from drought impact and even greater weed pressure. Many producers applied pesticides again for the sake of their yield around the "normal" harvest window of August, but were then hit with additional, unexpected rainfall. This final rainfall not only washed off the applied pesticide a second time but postponed the harvest season. At the time of the interview, (Sept. 28, 2025), many producers in central ND were still harvesting their wheat crop from the season (K. Harmel, personal communication). Crop production timing relies on precipitation patterns, and today's increasing precipitation variability is making production economically and environmentally vulnerable.

Challenges Related to Soil Health

Precipitation irregularity not only impacts crop production timing but also has substantial effects on soil health. In agriculture, minimizing soil disturbance and maximizing surface cover is the most effective way to maintain, or even enhance, the health of a landowner's soil. By minimizing disturbance and maximizing coverage, soil-water infiltration capacity is strengthened, and soil health is maintained. This is integral to crop production as precipitation patterns become more irregular and unpredictable, because the health of a soil dictates the availability of water to the crop. A healthier soil can then moderate precipitation extremes, which could be a determining factor of drought resilience.[9]

Accounting for crop residues in agriculture is one of the most proficient ways to both minimize soil disturbance and maximize soil surface coverage. Crop residue, the remaining biomass of a crop after harvest that includes stubble and chaff, is a large factor in soil surface coverage when less disruptive agricultural practices are implemented. Not only are crop residues an input of organic carbon and nutrients into the soil, but the physical residue is essential to water retention.[3] Stubble biomass decreases soil compaction, which increases surface infiltration ability and precipitation capture. Soil aggregation, or structure, is a product of crop root systems, which can also be crucial to the infiltration ability of a soil. Residues also help to protect the soil surface from high wind speeds by creating a small-scale windbreak.[5] Crop residues are important for decreasing soil erosion from both wind and water, therefore maintaining the overall health of a producer's soil in times of unpredictable precipitation.

Making Strategies Worthwhile

No-till, stripper header utilization, and cover cropping are current agricultural strategies that support soil health, and in turn may help to mitigate precipitation variability. No-till, the absence of tillage before planting, is already commonly adopted by many producers for allowing residues to keep soil intact and increase soil water storage.[5] Even though no-till is commonly adopted, some ND producers prefer to do a rotational tillage method. This includes tillage once every 3-4 years, or longer, to break up possible compaction that still occurs with crop residue in times of drought, which ND is prone to. No-till has been an easily adopted strategy because asking producers to abandon a practice, and in turn "lighten their load," has proven easier than implementing other mitigation strategies.

Stripper header utilization has also gained traction from producers as an efficient water-use strategy in the face of unpredictable precipitation. A stripper header, compared to a conventional header, leaves higher stubble that offers more soil stability and water infiltration capacity while maintaining crop residue biomass. Harmel approached stripper header technique advancements with optimism, but relayed that crop rotation must be considered prior to utilization. In the early growing season, Harmel's neighbor's soybean crop that was planted in high stubble left behind by a stripper header expressed growth deformities. The shade from high stubble at the time of emergence reduced growth, as high amounts of sunlight are essential to soybean growth. This resulted in a diminished yield for the producer at harvest time, which can make or break profitability. Even though tall residues may be effective for increasing water retention, maintained or increased yield productivity may not be directly linked to the technique without intentional crop rotation.

Cover crop implementation is not new in North Dakota agriculture, as existing federal and state soil health programs help to incentivize ND producers to plant cover crops with grant funds. Cover cropping is the practice of planting a crop to maintain soil surface coverage. In North Dakota, this often includes planting the cover crop in late fall after harvest of a producer's cash crop, or early spring before the planting of the cash crop. Common cover crops include rye, winter wheat, oats, clover, and radishes. Each crop is chosen for specific benefits, and sometimes for grazing, but all help to maximize soil surface cover and reduce erosion potential.9 Many producers still feel deterred from utilizing cover crops because of the cost, time, and effort that goes into planting and harvesting another crop at a different time of the year. At times, the program's offer of money is not incentive enough for producers to work overtime. It can even be "economically risky" in the short-term for producers to adopt the practices of both planting and harvesting, as the payoff is linked to future improvement in yield from soil health improvements of increased water re-

tention, rather than to an immediate profit.[4] Increases in cover crop implementation in North Dakota will be more likely when implemented alongside grazing practices. This would allow producers to cut the cost of harvesting the crop but still earn a return in the form of soil aggregation and infiltration ability of their field. In turn, future crop production may be more climate resistant because of increased soil health. With grazing of cover crops, soil aggregation and water capture as a soil health parameter are maintained.[4] This suggests that the grazing practice itself does not pose a risk to the water retention of the soil when concurrent with cover cropping. Implementing grazing practices alongside cover cropping may not be easy for producers without livestock, but a producer could lease the cover crop for grazing rather than starting a livestock operation. This would allow them to not only profit in the short-term from the lease income, but also in the long-term in regard to the health of their soil. If a producer already has a livestock operation, they will be able to cut the cost of buying feed if utilizing grazing with cover cropping, while also reaping soil health and water retention benefits.

Conclusion

As precipitation becomes increasingly more irregular and unpredictable with rising carbon dioxide levels, soil health and crop production timing are being impacted. To minimize these potential pressures of precipitation variability on agriculture, North Dakota producers have begun to utilize and develop water efficient strategies for maintaining yield. Assessment of producer insights regarding no-till, stripper header utilization, and cover cropping as mitigation strategies are integral to address the impact that variable precipitation is having not only on production, but also on our producers. This returns to the question, "How do unpredictable precipitation patterns affect the adoption of sustainable agriculture practices in North Dakota?" Producer insight concluded that eliminating a practice, in this case tillage, proves easier than integrating practices as mitigation strategies because of the workload and costs associated with the latter. The integration of water use efficiency strategies is intensive, especially cover cropping, but the long-term benefits are increased soil health and production resiliency leading to an overall greater agricultural integrity. Increases in precipitation variability are leading to agricultural vulnerability, and producers need support to make mitigation strategies environmentally and economically worthwhile. Reliable precipitation is an essential component of agriculture, and helping landowners navigate the challenges of increasing precipitation irregularity should be a priority.

About the Author

Alyssa Harmel recently graduated with a bachelor's degree in Environmental Sciences and a minor in Soil Science from Montana State University. While at MSU, she conducted research in collaboration with the Bozeman Fish Technology Center and the Montana Space Grant Consortium. To continue her environmental research journey after graduation, she has been accepted into the Natural Resource Sciences master's program at North Dakota State University. When she's not in the field or the lab, she's probably reading about or pursuing conversations about land stewardship.

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How Queer is Too Queer: The Homoerotic Subtext in Nella Larsen's Passing as Situated in the Harlem Renaissance

By Dru Holien

Abstract

This essay examines Nella Larsen's *Passing* (1929) as a text layered with homoerotic subtext, arguing that Larsen deliberately embedded queerness—both racial and sexual—within the novel's narrative structure. Written during the Harlem Renaissance, a period that encouraged Black artistic expression, Passing uses the motif of "*passing*" not only as a commentary on race but as a subtle exploration of same-sex desire. The essay contends that Larsen's repeated use of the word "queer," understood in the 1920s as odd or different, functions as a linguistic flag for the sexual deviance that circulates beneath the novel's surface. Drawing on Cheryl D. Hicks's historical analysis of Black identities and expression, women's sexuality in particular, and Alain Locke's framing of Harlem as a site of self-determination, the essay situates Irene and Brian Redfield's lavender marriage within the era's contradictory impulses: creative freedom on one hand, social surveillance on the other. This marriage is read not as a companionate partnership but as a performative shield against the judgment inflicted upon openly queer individuals. While early twentieth-century literature rarely depicted explicit homosexuality, *Passing* achieves its queer critique through indirection: symbolism, silence, and narrative restraint. The novel thus explores the Harlem Renaissance's "New Negro" as depicted by Locke by revealing that, for figures like Irene and Brian, genuine self-expression remained inaccessible. The act of *passing*, in Larsen's hands, becomes dual—racial and sexual—and the novel itself becomes a complex artifact that insists upon the inseparability of racial authenticity and sexual truth. Passing does not merely include queer subtext; it is structured by it, and Larsen's deliberate ambiguity is not evasion but critique.

How Queer is Too Queer

Queerness, particularly in the context of Nella Larsen's Passing, does not solely regard the contemporary idea that *queer* is a sexual orientation and/or identity. In Larsen's time, the word queer meant odd, puzzling, or simply different; it had not yet been popularized as a derogatory term or slur used toward members of the gay community. Throughout *Passing*, she repeatedly uses *queer* in this context. Though *queer* was not related solely or specifically to the gay community in the 1920s, being gay was viewed as odd, different, and wrong; therefore, the word *queer* would have applied to this community. Originally published in 1929, *Passing* was written during the Harlem Renaissance—a movement within the arts and culture of the Black community in New York—which provided encouragement and space for the expression of queer new ideas and identities. Larsen, through the close third-person narration following Irene Redfield, mentions, discusses, and implies many queer ideas throughout *Passing*, but she never explicitly mentions homosexuality; the *queer* concept of homosexuality is hidden in various exchanges and information that can be extricated from the text. Though it is possible this was not an intentional choice, especially considering relationships between two women were not well represented in the literature of Larsen's time, the deliberate detail and symbolism Larsen uses throughout *Passing* indicate otherwise. Larsen made the conscious choice to surround Irene Redfield and Clare Bellew's relationship with homoerotic subtext to add another layer of queerness and diversion from the status quo to her novel.

The entirety of Larsen's *Passing* discusses the idea of portraying yourself as someone that you are not, and while the primary focus of this theme is race, it may also be discussed as applied to sexual attraction. The concept of "*passing*" by identifying oneself publicly in a manner less than true biologically applies not only to Clare's *passing* as White but also to Irene, Clare, and Brian Redfield as attracted only to members of the opposite gender. The characters in this novel use *passing* as a means to gain security and freedom from harsh and harmful judgment. Clare uses her light hair and skin to pass as White to avoid the oppression and degradation that she was taught comes from being Black, while Irene and Brian use their marriage to pass as a heterosexual couple to avoid the judgment inflicted upon members of the gay community. Though they have access to communities that offered potential aversion from this judgment, they value their middle- to higher-class statuses—safety and security—more than genuineness in their identities; to be different is to risk comfort.

During the Harlem Renaissance, the rising number of out, or public, same-sex individuals and couples caused various uproars surrounding its controversy. As a movement within the arts, particularly literature, in the 1920s and 1930s, the Harlem Renaissance was a turning point in Black culture, creativity, and lifestyle. Philosopher Alain Locke developed the significant role Harlem played in the shaping and expression of Black Americans' identities in his 1925 analytic essay "The New Negro." To Locke, Harlem was "a race capital," a place where "Negro life [was] seizing upon its first chances for group expression and self-determination" (Locke 1925, 7). Identity and individuality were critical components of the Harlem Renaissance, and Harlem offered a physical space in which these concepts could be explored. However, this exploration was not entirely at liberty; societal and social expectations still imposed a level of restraint on this community. Fear of judgment and degradation provided invisible and unspoken boundaries for how and where people freely expressed themselves. Cheryl D. Hicks discusses the aforementioned rise in public expression of same-sex attraction and its partnered controversy in her 2009 article "'Bright and Good Looking Colored Girl': Black Women's Sexuality and 'Harmful Intimacy' in Early-Twentieth-Century New York," primarily in the section "Regulating Black Women, Regulating Harlem." She briefly focuses on the critic Reverend Adam Clayton Powell and his conflation of same-sex attraction between women and the predatory relationships uncovered within the church (Hicks 2009, 439); this idea was widely accepted and therefore widely spread. Even though Harlem was recognized as flourishing in culture and explored various forms of self-expression through music and art, the culture still had their boundaries surrounding public portrayal of sexuality. In private, at parties and underground clubs, people were more likely to express their sexuality, but in public and open places, leaders were cautious about the confluence of art, music, and other entertainment with extramarital sex (Hicks 2009, 438).

Black women in the early twentieth century received extensive judgment simply as sexual beings like any other human, and with the added retribution from this erroneous claim that women engaging in same-sex relationships are abhorrent predators, it is understandable that Irene would not want others to perceive her that way. To Irene, "security was the most important and desired thing in life. Not for any of the others, or for all of them, would she exchange it" (Larsen 1929, 132). *Passing* as a straight Black woman is crucial to Irene because any other expression would greatly threaten and risk her reputation and security. She would not be able to maintain her social standing and high-class reputation if she acted on any urge that deviated from the upheld status quo. Because Brian could not pass as White, Irene only does so out of convenience when she is alone, but never socially (Larsen 1929, 120); she never passes as a White woman solely in order to earn the social respect of White people. Irene and Brian together do not pass as White, but they do pass as heterosexual; while they cannot use fair skin to earn a respectable status at a glance, they can use their perceived sexual orientation.

Irene and Brian got married not for love but for safety. Their marriage is a charade that protects them from the dangers of pursuing what they truly want hidden deep inside. The main clues Larsen gives that imply Irene and Brian may be in a lavender marriage are found in their lack of sexual intimacy and separate bedrooms. Though a lack of sexual or emotional intimacy often indicates a relationship that is unhealthy rather than completely a lie, it is made clear that Irene and Brian are not intimate with each other because they experience same-gender attraction. To Brian, Irene is the mother of his children and nothing more (Larsen 1929, 112); to Irene, when compared to Clare, who clouds all Irene's days, Brian is just " the father of Ted and Junior" (Larsen 1929, 111). The couple respects each other and appreciates their role in parenting their two children, but they have no love or passion for each other on their own.

While the homoerotic subtext surrounding Irene and Clare's friendship has been a well-discussed subject since the release of *Passing*, many scholars overlook the intimation of same-sex desire within Brian's character. Early in the novel, when prompted about the women who visit her husband as a physician, Irene states, "Brian doesn't care for ladies, especially sick ones. I sometimes wish he did" (Larsen 1929, 45). This shows that she is aware of her husband's disinterest in women and recognizes that it extends beyond herself. Irene's observations and descriptions of Brian as attractive but not at all "pretty or effeminate" display

her desperation to see him as masculine (Larsen 1929, 61). If Larsen had only written Irene's description of Brian as good-looking and masculine, it would not have begged for further analysis, so she included the words "pretty" and "effeminate" with the intention of showing Irene's struggle to continue ignoring Brian's homosexuality. When Irene introduces Junior's "queer ideas" about sex to Brian, he supports his son's exploration of sex as a joking matter (Larsen 1929, 67). Junior, as his name is Brian Jr., is a projection of Brian's own struggles with sex and sexuality. By arguing that it is important for Junior to learn about sex as a great joke, Brian shows the readers that he too views sex—namely heterosexuality—as a joke. By stating that "It'll keep him from a lot of disappointments later on" (Larsen 1929, 68), Brian implies that he has been greatly disappointed by the norms of heterosexuality and wishes he had learned his own truth sooner.

Following Irene's previously mentioned claim that Brian does not care for women, she claims that it is South America that attracts Brian's attention (Larsen 1929, 45). His obsession with Brazil is yet another point that clues readers in to his queer desires because of its exoticism, racial integration, and reputation for sexual freedom throughout modern history. Irene's thought that Brian is "Forever wanting something that he couldn't have" (Larsen 1929, 11) is aimed directly at his want to move to Brazil and indirectly proves her knowledge—and denial—of his same-sex desires. Further in the text, Irene becomes overwhelmed by Brian's increased restlessness, irritability, and withdrawal from her and their children, and hopes that this change in his demeanor is due to his yearning to be in Brazil, away from Harlem (Larsen 1929, 102). Aside from his restlessness, Irene also ponders his possession by "some intense secret satisfaction" (Larsen 1929, 102), which, along with the friendship that has developed between Brian and Clare, leads her to the conclusion that Brian is having an affair with Clare.

Superficially, readers could assume that Irene becomes filled with rage at the thought of Brian and Clare having an affair because it has drawn her husband's attention away from her and their sons. However, in reading this novel as a subtle commentary on sexuality, it becomes more likely that Irene is upset because she herself is infatuated with Clare and is jealous of Brian's imagined ability to grasp her attention. Irene's obsession with Clare develops from the beginning of *Passing* with her descriptions of Clare as a "lovely creature" (Larsen 1929, 16), "catlike" (Larsen 1929, 5), and "attractive-looking" (Larsen 1929, 12). When Irene notices this woman staring at her on the rooftop at the Drayton, her first concern is not that the woman knows she is not White, but that her appearance is less than perfect (Larsen 1929, 13). If Irene were not attracted to and therefore flustered by other women, she would have first been concerned that this woman did not believe she belonged at a Whites-only hotel. Though Irene's enamorment with Clare passes as being solely due to her dangerous lifestyle of *passing* as White, her thoughts and actions toward Clare indicate more. Irene struggles with knowing whether she wishes to be Clare or *be with* Clare, so she chooses instead to remove her from her life. Though she wants separation from Clare, Irene cannot stay away from her as Clare pushes her way into Irene's life. As Irene rehearses her speech to Clare for refraining from being a part of each other's lives under the disguise of protecting her, Irene is cut off by Clare's soft, sneaking entrance to her room (Larsen 1929, 75). The "inexplicable onrush of affectionate feeling" (Larsen 1929, 75) Irene experiences after Clare kisses her head highlights the overwhelming loving emotions she has for Clare. The sort of affection that arises in Irene is meant to be reserved for her partner, and she is aware of this; it only convolutes her emotions more.

Confusion and uncertainty threaten Irene's pleasant and secure—though unfulfilling—lifestyle. Clare Kendry's presence threatens Irene's security because she does not know what their future holds; she does not know what emotions will build up or what she may do when they force their way out. Even after concluding that Clare and Brian were not having an affair, Irene still wants to be rid of her, to be rid of her "furtive comings and goings" (Larsen 1929, 117). Clare's catlike ability to insert herself into Irene's life regardless of the consequences increases the danger of her presence because Irene has no control over her. The danger that surrounds Clare that Irene is so afraid of is not her choice to pass as White; it is Irene's attraction to her. Irene masks her feelings for Clare and uses Clare's lifestyle to account for her aversion. Throughout the text, Irene portrays more passion for Clare than for her husband or her sons. The intensity of her emotions increases from child-like curiosity to an internal fire. The increase in passion is shown by Larsen's use of exclamation points and sentence breaks as Irene becomes more encapsulated by her feelings. Given that the desires discussed are portrayed only in subtext and details such as punctuation, it could be said that Larsen did not intend for this meaning to be derived from *Passing*. Modern literature—what Larsen was primarily exposed to—focused more on relationships between men and women, rather than those between two members of the same sex. It was common to write about friendships between men and women with added attraction and passion because heterosexuality is the norm. With this being the form of literature Larsen likely grew up reading, it could change her ability to effectively and accurately write about friendships between women who have no attraction toward each other. However, the homoerotic dynamic between Clare and Irene is not the only form of same-sex attraction found in the book. While this layer of queerness could have been entirely unintentional, Larsen is too careful and meticulous in her writing to not realize what she was creating.

Nella Larsen purposefully and intricately weaves layers of queerness into the narrative that is *Passing*. Though her use of the word *queer* in the novel was never specifically used regarding the gay community, it flagged the importance of same-sex attraction throughout the text. Through subtle narration, symbolic elements, and complex relationships between characters, Larsen created a textured portrayal of queerness that challenges the social norms of her time. The novel's exploration of *passing*—both racially and sexually—reveals how characters manipulate their identities to gain security in a world that demands conformity. The dynamic between Irene and Clare, filled with homoerotic subtext, mirrors Irene's inner conflict and her fear of the emotional and social repercussions of acknowledging her attraction to Clare. Similarly, Brian's complex relationship with Irene further hints at his own queerness, underscoring the novel's broader themes of repressed desires and the dangers of self-deception. Situating this struggle within the context of the Harlem Renaissance reveals the era's central paradox: it was a period that simultaneously encouraged the exploration of Black identity—and sexuality—while still enforcing the rigid social hierarchies that forced figures like Irene and Brian into lavender marriages. While Locke framed Harlem as a site of self-determination for the New Negro, Larsen's novel serves as a necessary counter-narrative, revealing that for *queer* individuals within that community, true self-determination often remained an inaccessible luxury, hidden beneath layers of *passing* and performance. *Passing* thus stands as a complex artifact of the Harlem Renaissance: a text that *queer*s the very idea of the 'New Negro' by insisting that the fight for racial identity could not be separated from the fight for sexual authenticity, ultimately offering a profound commentary on identity, sexuality, and the societal pressures that shape our lives.

About the Author

Dru Holien is a Senior at Montana State University, completing dual degrees in English Literature and Psychology. Originally from Minnesota, she moved to Bozeman to attend MSU in Fall 2022 and will graduate in May 2026. Upon graduation, Dru will attend the University of Minnesota to earn her Master's Degree in Integrative Biology and Physiology as a stepping stone toward her long-term goal of becoming a physician. Outside of school, she enjoys crocheting, baking, staying active, and spending time with friends, family, and pets.

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HC140005: Reflections in Brass

By Ginger Heath

Abstract

The French horn can serve as many things: a musical instrument, a source of great joy and frustration, a witness to growing up, and even a gateway to the past. At its core, this is a love letter to a horn that has been with the author for a quarter of its own life and half of theirs. Topics of reflection include accumulated physical changes to both instrument and player, the ever-strengthening connections between music and memory, and the active role of the listener in shaping the identity of that to which they listen.

As I walk home in the fading light of dusk, I can see that the back of my right hand is stained a familiar greenish blue. The tarnished area can be traced from the tip of my thumb to my wrist, then back up the side of my index finger, finally spilling across the backs of my fingers. The impression is that of a great, unnatural bruise. It is a Monday, so I have been in some form of rehearsal for five and a half of the past twelve hours. There are several competing lines of music stuck in my head that I am not yet eager to dislodge.

I started playing the French horn close to ten years ago. In addition, I have been playing my horn since the very beginning. It is a CONN 8D composed of nickel silver, an alloy similar to brass—copper and zinc—with the addition of nickel. Horns belong to the brass instrument family, named for the most common metal used in their construction. Instruments like mine tend to earn a sort of honorary "brass" status despite the compositional distinction between nickel silver and true brass. As a freshly initiated middle school musician who had only just memorized the phrase "CONN 8D," all I knew was that I played a brass instrument. Nickel silver or not, I was now connected to a family unlike any I had ever experienced.

Inside the flared bell of a French horn, the right hand is responsible for supporting the instrument and shaping the pitch. My horn's lacquer finish was stripped long before my time, leaving raw metal in most places, including the bell. When unlacquered brass meets moist air blown through the horn, the zinc in the bell oxidizes and forms a tarnish on any portions of the hand that make prolonged contact. A partially green hand is earned over the course of hours of playing and often fades away in just as much time. The same confluence of moisture, air, and brass that will tarnish a hand will also create an oxide layer on the surface of an instrument called a patina. In some cases, this is described as "satin," which is a more polite term for "dull." The way a patina forms is influenced by the unique body chemistry of the musician. In this way, even as it loses its shine, the surface of your instrument can become a reflection of yourself.

I have now been playing the same horn for almost half of my life. I can no longer remember which dents, scratches, and gouges were inherited and which were the product of a clumsy youth. In any case, I could recognize the instrument by touch alone. One of the places where the patina is strongest is at a portion of the wrapped tubing that I use as a handhold. Here, the surface of the brass reflects light in pinpricks of color, subtly iridescent. Nearby, the back of my forearm often rests against the outside of the bell. Sometimes dozens of times in a single rehearsal, I pin the instrument to my chest so I can pencil notes into my music. A bright verdigris, like those on my hand but more intense, occasionally forms on my instrument due to this repetitive motion. Along the rim of the bell, there is a jumbled collage of fingerprints and water spots. The ridges of my fingerprints have started to oxidize, becoming darker and more distinct on the surface of the metal. Some horn players choose to wipe these away with a cloth during each rehearsal, but I lack both the discipline and the desire. Further inside the bell, the darkness is interrupted by a muted patch of gold where the instrument rests against my right hand each time I play. The gleaming outlines of the fingers are the same size as my hands today, completely eclipsing the wear left by my smaller, younger hands.

My instrument is not the only one changed by our time together. I have developed much stronger lip, tongue, and jaw muscles as a result of playing. Collectively known as the embouchure, these muscles allow for precise movement between notes. In the middle of my left pinkie finger, on the side facing the ring finger, there is a small dent. Barely noticeable by sight, the divot is more obvious by feel. The metal hook on the left side of my horn, used by the pinkie finger to support the weight of the instrument, has evidently made a seat for itself in this dent.

When I look at my discolored hand, the tint is almost supernatural. The instinctual reaction is that this is the flesh of the dead, not the living. On closer inspection, there is a part of the living echoed by the tarnish: the veins running up the back of my hand. At the knuckles, where the external coloration meets the internal, there is a seamless transition. How I live and how I live become indistinguishable and inextricable.

Most would argue that time travel is not (yet) possible, nor multilocation—the ability to be in more than one place at once. People are limited to a set of coordinates and a singular timestamp at any given moment, and any other mode of existence is relegated to the world of science fiction. An exception to this lies within music. When I listen to Beethoven's *Symphony No. 7*, I am eighteen years old again, performing in socks because I forgot my dress shoes. If it is possible to play horn with a white-knuckle grip, that is what I am doing. I am also two years older, lost in the splendor of the music. My conductor is cocking an eyebrow at me; I have just missed my entrance. When I listen to Milhaud's "Le Boeuf sur le Toit", I am back home, learning to give in to the temptation of playing with reckless abandon. Otherwise, the music leaves me in the dust. I am also two states to the east, gleefully sharing several minutes more of the piece with my classmates than I was to be allotted that day. I will take as much as I can possibly get. When I listen to "Saint-Saens' Romance", I am butchering the solo in a way that is so very characteristic of a beginner horn player. There is beauty somewhere here, but it is hidden from me behind nerves and cracked notes. I am simultaneously a decade older, standing thigh-deep in an Oregon lake and playing for barn swallows in the evening light. There is beauty everywhere now, and seeing it is so easy. Through every piece, I am as old as I have ever been and always changing, living in my present yet dancing with my past. When I listen like this, with one foot here and the other in those moments, I become the person I lost somewhere in the years between. The versions of myself that I forgot to mourn are still held safe within the music.

As I have grown older, a process that was once obscure to me has come into sharp focus. There is a patina forming on the music, unique to my own experience. My fingerprints are everywhere. Oft-handled sections have grown dull and iridescent—predictable yet all the more meaningful. The sweat of my hands has left the outline of my presence in every horn line I have ever played, even when I am not the one playing it now. Layer by layer, this is the transmutation of both the glorious and the mundane into an enduring record of my life.

Oscar Navarro's *El Arca de Noé* for symphonic orchestra tells the story of Noah's Ark. This piece is a tone poem that includes sections dedicated to the word of God, great beasts, soaring birds, lullabies on the Ark, the gathering storm, and the great Flood. About three quarters of the way through the piece, as the floodwaters recede, a changed landscape is revealed to Noah. This final section, directly following "Destruction," is titled "The New Earth." A great silence is punctuated by flute, mimicking the call of a dove, which is then joined by a lone horn. The vast, unfolding melody, carried by that horn in the wake of such devastation, is the most beautiful solo line I have ever known.

Each time I listen to *El Arca de Noé*, a part of me returns to the day I recognized this music for what it means to me. I am winding my way through the Columbia River Gorge as sunset shifts into night, sharing the view with a friend in the passenger seat. Percussive thunder blasts through the speakers, and even though the summer sky is completely clear, I can see thunderclouds on the horizon once more. For the next twenty minutes, I can see years into the future when I am usually limited to weeks or even days. The horn solo approaches, and even though I am not the one playing it this time, my heart rate picks up. I remind myself to breathe deeply. Tonight, I can see that the floodwaters have receded after an endless, looming storm. At twenty-one years old, I feel I have already lived a lifetime. My new earth is a purple sky reflected in the waters of the Columbia River, and the lilting call of the olive-backed thrush, and every other gorgeous moment I can eke out of uncertainty to share with the people I care about.

Each time I listen to *El Arca de Noé*, another part of me returns to the day I first heard it. I am navigating the stretch of I-90 between Spokane, WA, and Bozeman, MT, twenty years old and equal parts eager and anxious for the coming fall semester. Intentionally unaware of the intended story within the piece, I let the contours of the music take the shape of my surroundings: folding landscapes, steep mountain passes, and a distant thunderstorm. The day's threats are becoming challenges echoed in brass fanfares and punc-

tuations of chaos. Within the music there is a section titled "The Storm," complete with raindrops, croaking frogs, and a building sense of dread, but this is something I will only learn later. For now, the storm on my own horizon silently rages, arcs of lightning both majestic and delicate in the late summer air. Each time the piece ends, I loop back to the beginning. There is something almost intimate about experiencing the world through the lens of music so perfectly. No one else will ever experience this moment with me, and if they could, it would never be in quite the same way. With every mile, up steep passes and down to the valleys below, the storm and I grow closer to one another. As I take my exit into Bozeman, we meet in a deluge of rain and hail so powerful I can no longer see the car in front of me. The water is all-encompassing, yet within ten minutes, the sun has returned.

Each time I listen to *El Arca de Noé*, a third part of me returns to the day I performed it. I am sitting at the head of a row of three other horn players. Between loud, brassy elephant calls and acrobatic passages, the pull of a smile is irresistible. Then, as the storm abates and the waters recede, there is the solo. My body sees it as a threat, throat tight and mouth dry. The passage on the paper in front of me, messy with graphite, has been marked by two sets of hands over the last two months. This is a challenge I am willing to face. At this point, I have yet to successfully, cleanly hit the highest note in the presence of my orchestra, let alone the crowd assembled before us tonight. The orchestra fades and I feel a bit light-headed, but my conductor smiles at me and I find myself able to smile back. I breathe in. I play. A threat becomes a challenge that becomes a triumph.

During the lulls of an orchestra rehearsal, there are pinpricks of color shining in the dullest parts of my horn. It feels like an iridescence that, in that moment, exists only for me. The music somehow feels exactly the same. Everyone is listening to the same notes, but none of us hear it quite the same way. The well-loved places in the music, different from person to person, have become shimmering portals to another time. We are all communing with people whom we will never meet.

It is a privilege to love something long enough to let it see you change. A complex system of metal tubing has borne witness to the tail end of my childhood and a tumultuous adolescence, and I know there will be changes yet to come. Someday, I will listen to Steven Bryant's Dusk without crying. The coming night will not loom quite so large. I will be able to see the next dawn in the hues of the setting sun. Goodbyes will hurt in a different way.

Of course, by then, I will not be the person listening anymore. That is a job for someone new; I will have become just another ghost haunting the music, waiting to be recalled.

About the Author

Ginger Heath is a senior at Montana State University majoring in Paleontology. They currently study French horn under Dr. Elizabeth Schmidt. Ginger is a veteran member of several MSU music ensembles, including the Symphony Orchestra, the Horn Ensemble, and the Bitterroot Brass Quintet. In the past, they have also been a member of the Portland Youth Philharmonic, the Clark College Symphony Orchestra, and the Northwest Symphonic Pops Orchestra. In their free time, they enjoy designing concert posters, reading about historic polar voyages, and rockhounding on the banks of the Yellowstone River. After graduation, Ginger plans to attend taxidermy school.

The Skin Microenvironment and *Staphylococcus Epidermidis*: A Comprehensive Overview

By Jack D. Weide

Abstract:
The human skin microbiome is an extremely diverse and variable environment which plays a critical role in the maintenance of barrier integrity, immune regulation, and protection against disease. Among its many inhabitants, *Staphylococcus epidermidis* stands out as both a commensal and an opportunistic pathogen making it extremely relevant in skin microbiome research. This review investigates how factors such as moisture, pH, nutrient availability, and immune activity impact microbial diversity across dry, moist, and sebaceous regions. The dual role of S. epidermidis is explored through its role in immune priming, wound healing, and colonization resistance, alongside its involvement in biofilm formation and skin disorders including atopic dermatitis and rosacea. Emerging in vitro and in vivo skin models are also assessed for their flaws and strengths in replicating human skin conditions. Together, these insights highlight the balance in host-microbe interactions and the areas in current research that need to be further studied.

Introduction

The integumentary system in the human body plays a pivotal role in protecting the body from many external stressors such as temperature, the chemical environment, and bacteria.

Amongst the 19 phyla and ~1,000 different species of bacteria present on the skin, the two bacteria most common in skin microbiome research are *Staphylococcus epidermidis* and Cutibacterium acnes.[1,2] This prevalence of the two species in skin microbiome research results from their prevalence and their roles as both commensals and opportunistic pathogens in the human integumentary system. This review explores the characteristics of the skin microbiome, the impacts of these characteristics on microbial diversity and concentration, S. epidermidis as a commensal and opportunistic pathogen, and the progression of skin-relevant models for skin microbiome research.

Overview of the Skin Microenvironment

The cutaneous membrane is the largest organ in the human body and is typically divided into 3 layers: the epidermis, the dermis, and the hypodermis, each with their respective roles in skin health and impacts on the skin microenvironment and microbiota.[3] The two most important layers for this review are the epidermis and the dermis.

The outermost layer, the epidermis, is composed primarily of stratified squamous epithelial cells with a high concentration of keratinocytes, which produce lipids, an important factor in the waterproof behavior of the skin.[4]

The dermis, the secondary layer of the skin, contains nerves, hair follicles, collagen, immune cells, sudoriferous glands, and sebaceous glands.[1] The hair follicles, immune cells, sudoriferous glands, and sebaceous glands are of particular importance when discussing the skin microbiome due to their roles in nutrient availability and the physical environment.

Skin Biodiversity in Dry, Moist, and Sebaceous Conditions

The skin's environment is incredibly variable and hostile, with many factors that work against microbial growth. Despite this fact, the skin microbiota exhibits a high degree of variability, and certain regions are characterized by dense microbial colonization.[5] Factors such as nutrient availability, moisture levels, immune activity, pH, and oxygen variability or availability impact biodiversity and bacterial growth across skin regions.

In general, the skin has three different types of moisture areas which have varying oxygen saturations to accompany them. Dry areas (limbs) and moist areas (underarm and navel) have high oxygen saturation selecting for aerobic bacterial growth, and sebaceous areas (head, chest, and back) have low oxygen saturation favoring anaerobic bacterial growth, especially within the hair follicles.[6,7]

Another important factor in skin microbial biodiversity is nutrient availability in the various skin microenvironments. Dry areas have a low nutrient availability due to their low concentration of hair follicles, sudoriferous glands, and sebaceous glands. Due to the lack of nutrients in these areas, they exhibit the lowest microbial density.[8] These areas, although lacking in nutrients and microbial density, have the highest microbial diversity. This can be attributed to the lack of a dominant nutrient niche for one species to dominate.[5] Moist areas, in comparison, have a high concentration of sudoriferous glands, and some have high concentrations of hair follicles (e.g. axillary vault). These sudoriferous glands are responsible for the secretion of sweat, which is rich in water, electrolytes, urea, lactic acid, and glucose.[9] The presence of electrolytes in these areas allows for growth of halophiles such as members of the Staphylococcus genus and some members of the Corynebacterium genus, those making up the highest percentage of the microflora within these environments.[1,10] Sebaceous areas of the skin are the most nutrient-rich skin environments, fostering the highest biomass due to high nutrient concentration, but the least microbial diversity due to the specified and unique nature of the nutrient composition. The sebaceous areas of the skin contain both sudoriferous glands and sebaceous glands as well as hair follicles. The sebaceous glands produce sebum, a lipid-rich substance that is composed of triglycerides, free fatty acids, wax esters, and squalene (a chemical responsible for moisturizing the skin). The nutrients present in the sebum provide a unique energy source specific to lipid-metabolizing bacteria such as members of the Cutibacterium genus, while the nutrients from the sweat continue to select for halophilic bacteria.

The pH of the skin is also a significant factor in the composition of skin microflora and the diversity of microbial communities across the various environments within the skin. The average pH of the skin is a high area of contention within dermatologic research, with studies claiming the average pH of the skin is anywhere from 4.0 to 7.0 pH.[11] This is narrowed to a range of about 4.5 - 5.7 whenever the skin is not exposed to cleansers and cosmetics for 24 hours. Although this is the generally accepted average pH of the skin mantle (the surface of the skin), it is important to note that pH, like oxygen saturation and nutrient composition, also varies between the dry, moist, and sebaceous areas of the skin. To maintain this acidic pH range, the skin releases fatty acids from sebaceous glands, as well as lactic acid and electrolytes from sudoriferous glands.[1] This suggests that sebaceous areas of the skin would be the most acidic, followed by moist areas, and then dry areas with the least acidity. Because most microflora flourish in environments with basic pH conditions, the skin provides a unique environment where only acidophiles or acid-tolerant bacteria can survive. This pH sensitivity in microflora explains, in part, why dry areas support greater biodiversity, whereas moist and sebaceous areas have less biodiversity and a more selective environment. PH-driven variation in microbial communities plays a crucial role in skin health. Many constituents of the skin microflora play a crucial role in skin barrier function; thus changes in pH of the skin mantle can cause certain bacteria to lose their functionality in the barrier or even to become opportunistic pathogens causing skin dysbiosis.[12] This leads us into our next section, exploring the skin's immune activity and its impact on microbial diversity.

Not only does the skin serve as a barrier against physical factors, but it also serves as an active component of the immune system that together works with resident microbiota to protect the body against pathogens.[8] The skin's immune function plays a central role in shaping microbial diversity across the different areas of the skin. The skin's immune system is made of both innate and adaptive components, this includes immune cells, antimicrobial peptides (AMPs), and specialized skin structures such as the skin-associated lymphoid tissue (SALT).[13] The interface between the body's immune system and the skin microbiota significantly influences the microbial composition of the skin.

The innate immune response of the skin is the first immune response involved in the skin's defense against external pathogens. It consists of physical barriers like the stratum corneum, and active components like keratinocytes' pattern recognition receptors (PRRs), which initiate the secretion of AMPs that inhibit microbial growth in the targeted microbes.[8] In areas characterized by a high concentration of skin microbiota, like the sebaceous and moist areas, this immune activity is critical for maintaining microbial balance. AMPs are thought to be involved in managing microbial density by limiting the overgrowth of beneficial microbes like C. acnes and killing pathogenic microbes like S. aureus.

The adaptive immune response is also integral in the regulation of skin microbial diversity. Specialized cells like T-cells, dendritic cells, and macrophages help detect and respond to microbial antigens.[13] Some research also suggests that resident commensals also influence the skin's immune response. For example, S. epidermidis colonization of the skin has been shown to cause increased levels of cytokine interleukin-1α(IL-1α), a cytokine associated with the inflammatory immune response of the skin.[14,15]

Imune activity in the skin also varies across the moist, dry, and sebaceous skin zones. Sebaceous areas such as the forehead and nose, rich in sebaceous glands, have a more acidic pH as previously discussed. The immune system in sebaceous areas is more specified to target lipid metabolizing bacteria such as C. acnes and S. epidermidis the two most common microflora in the sebaceous areas of the skin.[13,14] The sebaceous glands in these areas release defensins, cytokines, chemokines, and other chemicals that target lipid metabolizing bacteria to help regulate the concentration and the composition of these areas. In moist areas, a similar immune response exists where halophilic or sweat-tolerant bacteria such as Corynebacterium and Staphylococcus are targeted by AMPs released by the eccrine glands or sudoriferous glands. AMPs such as dermcidin released in eccrine sweat don't play a normal role in skin immunity like other AMPs. This AMP binds to the bacteria resulting in reduced RNA and protein synthesis. As a result, it helps control the proliferation and density of bacterial colonies in the moist areas of the skin. Recall that dry areas of the skin tend to have the highest microbial diversity in the skin due to their nutrient composition and pH. Because of this, the immune system in this area is less specified due to its exposure to a broad range of bacteria. Thus, it exhibits a more typical innate and adaptive immune response when looking at skin immune function. This allows for the microbial diversity of the dry areas to be maintained and for the skin to regulate a broad range of bacteria to prevent overgrowth of a specific type leading to an imbalance in the skin microbiome and conditions of skin dysbiosis such as psoriasis, eczema, or rosacea.[1]

Staphylococcus epidermidis

Staphylococcus epidermidis, a gram-positive coagulase-negative bacteria, is one of the most prominent species of bacteria present in the varying skin microbiomes.[1] Often referred to as a major "skin sentinel," S. epidermidis plays a dual role in the skin as both a commensal organism and an opportunistic pathogen.[16] In homeostatic skin conditions, it actively primes the cutaneous immune response, aids in maintaining homeostasis, and prevents other opportunistic pathogens from causing disease through colonization resistance. Due to its prevalence in the skin compared to other microflora, along with its functional importance in skin health and its dual role in the skin, S. epidermidis has been selected as a critical model organism for understanding the dynamics and conditions of the skin microbiome. As such, in this section we will discuss its priming of the cutaneous immune response, how it aids in the maintenance of homeostasis, its colonization resistance, and its role in two of the most common forms of skin dysbiosis, atopic dermatitis and rosacea.

S. epidermidis as a commensal organism plays a functional role in skin health. Whether it's immune priming, responding to barrier injury, or contributing to colonization resistance, this bacterium is a major player in the prevention of infection and maintenance of skin homeostasis. In this section, we will discuss how S. epidermidis fills these roles and why it is so important.

One of the ways that S. epidermidis impacts the skin microbiome and aids in the immune function of the skin is through priming host cells for immune response. S. epidermidis has been shown to do this in many ways. One way it does so is by early colonization of the host skin microenvironment. It has been shown that this early colonization, specifically within hair follicles, induces the chemokine CCL20 and the migration of Treg Cells to the follicle following induction of said chemokine.[16]

Response to barrier injury is also a major factor when considering S. epidermidis's role as a commensal. Studies done on mice to determine S. epidermidis's role in skin barrier function have shown that S. epidermidis converts aromatic amino acids into trace amines which were shown to increase the rate of wound healing.[17] This increased wound healing rate helps prevent the colonization of wound sites by pathogenic bacteria which may cause inflammation and infection of the skin. The S. epidermidis also produced a molecule called 6-N-Hydroxyaminopurine (6-HAP) which selectively inhibited the proliferation of tumor cell lines in the mouse model and significantly suppressed ultraviolet tumor growth.[16] This is important because it shows how S. epidermidis not only strengthens our bacterial immunity but also suppresses and even prevents neoplasms of the skin.

The last major factor to consider when looking at S. epidermidis's role as a commensal is colonization resistance. S. epidermidis plays a crucial role in colonization resistance as a commensal organism, preventing the overgrowth of pathogenic microbes on the skin through various means. One of these means is via competitive exclusion. Being one of the most prevalent microbes on the skin, S. epidermidis is a dominant player in nearly every microenvironment within the skin.[5] This can be seen in the sheer volume of S. epidermidis present in the skin when compared to other skin microbes as stated previously in our section on nutrient availability impacts on microbial biodiversity. Additionally, S. epidermidis prevents pathogenic colonization of the skin through various other direct and indirect mechanisms. One such mechanism is the activation of the distinct innate immune response and the amplification of the keratinocyte antimicrobial immune response through the secretion of a certain unidentified factor or factors by S. epidermidis.[16] Another mechanism is the secretion of an unidentified small molecule (<2 kDa) by S. epidermidis, and subsequent activation of the keratinocyte aryl hydrocarbon receptor (AHR) and downstream IL-1α and human β-defensin 3 (hBD3) expression to promote an innate immune defense response.[13,16]

While S. epidermidis plays a crucial role as a commensal in the skin microenvironment during homeostatic conditions, under abnormal skin conditions it becomes an opportunistic pathogen commonly associated with both skin dysbiosis and nosocomial infection. In this section, we will primarily be covering the implications of S. epidermidis as an opportunistic pathogen in skin dysbiosis, though it is pertinent to consider that this research also has implications in the prevention and treatment of nosocomial infection.

The first thing that needs to be discussed when considering the pathogenic state of S. epidermidis is its proliferation into a biofilm and the lack of research done on same. The exact mechanism of biofilm formation by S. epidermidis is currently unknown, but the process itself has been broken down into four major steps: adherence, accumulation, maturation, and detachment.[18] A fully matured S. epidermidis biofilm contains an amalgamation of adhesive molecules, among which are polysaccharide intercellular adhesin (PIA), proteinaceous factors (Bhp, Aap, and Embp), teichoic acids, and extracellular (e) DNA. It has been identified that not all isolates of S. epidermidis present on the skin encode the factors that are believed to cause this biofilm formation. A study done by Bowden et al. stated that only 13 percent of colonizing skin flora isolates encoded Bhp, a protein that has been associated with the formation of strong biofilms by both S. epidermidis and S. aureus.[19] Given the role of S. epidermidis biofilms in conditions of skin dysbiosis and nosocomial infection, along with the lack of understanding of the mechanisms responsible for the formation of a mature S. epidermidis biofilm, future research needs to be focused on identifying these mechanisms and building an understanding of these prevalent and relevant biofilms.

The next thing to be considered is the role of S. eipidermidis in the various conditions of skin dysbiosis with which it's associated. The first major skin condition we will discuss is atopic dermatitis. Atopic dermatitis is defined as a chronic relapsing, pruritic inflammatory skin condition that is non-contagious, affecting approximately 15 percent of children in the United States at a given time.[20] It used to be associated with the colonization of S. aureus in the skin, but more recent research has shown that disease flares have been associated with an overall decrease in the diversity of the skin microenvironment in areas where the lesions form.[21] It also showed that both S. aureus and S. epidermidis were responsible for an increase in lesions and inflammation. Although this new research shows that both organisms are responsible for the flare-ups of this disease, it doesn't address the relationship between the two bacteria in this disease.

The other major skin condition we will cover is rosacea. Like atopic dermatitis, there are a plethora of holes in the research correlating S. epidermidis to the disease. Despite this, it seems to be commonly accepted that S. epidermidis is one of the primary bacteria responsible for the disease.[22] This idea was also supported in a study by Woo et al. that showed, via 16S rRNA PCR, that S. epidermidis was the most prevalent bacteria in pustules and skin sites of rosacea, making up 28 percent of the microbial population.[23] Despite this shared acceptance that it is one of the bacteria responsible for the skin condition, it is glaringly clear that further research into the disease and its correlation to S. epidermidis is necessary.

Skin Relevant Research Models

As stated previously, the complex and dynamic microbial community present in the skin microbiome plays a pivotal role in skin health, immunity, and disease prevention. As research on these microbial communities becomes more relevant, it is increasingly important that research models that accurately represent the skin are available.

In the past, much of the research done on human skin microflora has been done on in vivo models where mouse skin was used to represent the skin. The mouse model for skin microbiome research especially in the research of bacterial infections of the skin and immune response to them has proven to be a reliable model.[24] Despite its capabilities as a research model, the mouse model also has a plethora of shortcomings including inherent immunological and physiological differences between humans and mice. It has been suggested, however, that human skin xenografts on mice could aid in the mitigation of some of these physiological and immunological differences, though that remains to be proven.

Previous in vitro skin-relevant models for understanding the growth and metabolism of bacteria such as S. epidermidis and C. acnes have used high concentrations of nutrients and oxygen which despite giving an accurate representation of the optimal metabolism of said bacteria fails to represent the actual environment on the skin for which they're being studied.[1] Recent research has altered that though, using modified M9 salt media with nutrient, amino acid, and oxygen concentrations similar to what would be found in the different environments on the skin. However, this research falls short in its ability to accurately represent the moisture levels, temperature, and physical characteristics of the skin.

Conclusions

There has been immense progress in research on the characteristics of the skin microbiome, the impacts of these characteristics on microbial diversity and concentration, S. epidermidis as a commensal and opportunistic pathogen, and the progression of skin-relevant models of skin microbiome research. Despite this, there is still much research to be done on topics such as S. epidermidis's role in colonization resistance, specifically on the unknown small molecules that are secreted by it, as well as its role in various conditions of skin dysbiosis such as atopic dermatitis and rosacea. Additionally, the recent progress seen in skin-relevant research models is incredible, but there is still progress to be had in accurately representing temperature variance in different skin areas and understanding its impact on those areas. Overall, despite the incredible progress on skin microbiome and microflora research that has occurred over the last decade and a half, there are significant holes in our understanding of the roles of various bacteria in disease and how we can work to prevent them. Further discussion in future reviews should address the implications of bacteria such as S. epidermidis in nosocomial infection, as well as covering other prevalent skin microflora such as C. acnes.

About the Author

Jack Weide is a freshman at Montana State University majoring in Chemistry with a concentration in Biochemistry and a minor in Mathematics. Jack has worked in the Fields Lab of the Center for Biofilm Engineering since the beginning of his senior year of high school and has since pivoted to work in Computational Chemistry with the Mosquera group in the epartment of Chemistry and Biochemistry. Jack has lived in Bozeman nearly his entire life and enjoys skiing, hiking, and running. In the future Jack hopes to go to graduate school and to conduct research in Medicinal Chemistry.

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From Bioengineering to the Sun: A Summer in Solar Spectroscopy

By Rebekah Swanson

Abstract

During my time as a Summer 2025 intern with the Montana Space Grant Consortium at the Montana Learning Center (MLC), I gained experience with both astronomy education and research. My primary project involved learning to operate the MLC's spectroheliograph (SHG) to image the sun in the H-alpha wavelength. With no prior knowledge of solar photography, I studied observing methods, instrument focusing, and image processing using multiple types of software. I successfully captured and processed images throughout the summer, documenting prominences and other activity during the peak of Solar Cycle 25. To support the astronomical community, I compiled a series of guides, now published on the MLAstro website and available soon through the MLC, to help others approach solar imaging and spectroscopy with ease.

Introduction

Although I am a bioengineering major, astronomy, aerospace, and astrobiology—the study of the origin, evolution, and the future of life in our universe—have always been major interests and career goals of mine. Astrobiology often involves searching for key elements such as carbon, hydrogen, oxygen, nitrogen, and, in some cases, phosphorus, which are necessary to sustain life. One way to detect these elements without direct sampling is through spectroscopy, which identifies elements based on the specific wavelengths of light they emit or absorb.

I immersed myself in learning how to use the SHG: reading materials on solar observing, watching tutorials, and practicing setup, calibration, and image processing. Once I was prepared, I began imaging the sun in the H-alpha wavelength. Over the course of the summer, I captured images at various times and processed each set of images into one sharp photograph. This project allowed me to expand my technical skills as well as help future learners at the MLC and beyond.

Objectives

The primary goals of this project were to:

- Gain practical experience in solar imaging and spectroscopy.
- Learn and apply methods of calibration, data collection, and image processing in the H-alpha wavelength.
- Document solar phenomena during the solar maximum phase.
- Explore the connection between spectroscopy and astrobiology by observing how elemental signatures can be detected through light.
- Create user-friendly guides to support the astronomical community.

Methodology

Using the MLAstro SHG 700, I was able to image the sun in the H-alpha wavelength (656.28 nm). H-alpha corresponds to a specific transition in a hydrogen atom where the electron drops from the n=3 to the n=2 energy level. This transition emits a photon of light. H-alpha is visible near the red part of the electromagnetic spectrum (Spence, 2004).

For live capture of the spectra, I used SharpCap. The recorded spectral scans were reconstructed into disk images using J'SolEx. Image alignment and fine-tuning exposure was completed in ImPPG. AutoStakkert was used for stacking images.

The process of achieving proper focus is as follows:

1. Adjust the slit with the micrometer collimator.
2. Focus the spectrum using the camera micrometer.
3. Refine the spectral lines using the telescope's helical focus. (See Fig. 1.)

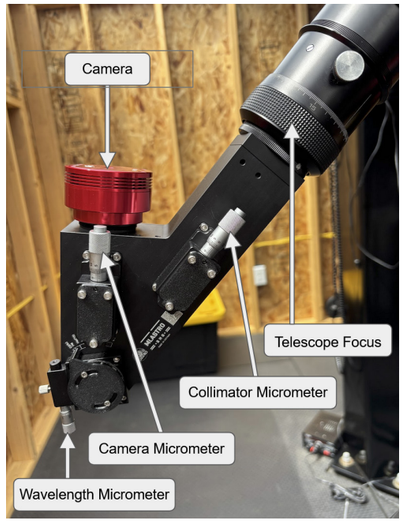

Figure 1. MLAstro SHG 700 with Labeled Key Components.

Results

Using this process, I obtained high-quality images of the solar disk in H-alpha. Imaging in H-alpha gave a good view of many solar phenomena such as filaments and solar flares erupting from the disk. As shown in Figure 4 and 5, several prominences were visible at the solar limb. Sunspots and surrounding energetic activity were evident (Figure 2 and 4).

Granulation —the textured pattern of convection cells on the sun's surface— is quite visible on the surface as well. Figures 3 and 5 highlight activity, with bright regions near the edge of the disk corresponding to active prominences. Figures 3 and 5, being negative, are particularly helpful at emphasizing subtle plasma flows and fine filamentary structures.

Using some functions in J'SolEx allows you to collect quantitative data. The Redshift function in J'SolEx will pinpoint and report the velocities of some areas where plasma is moving the fastest (Figure 6). Flow direction on the disk can be determined via Doppler mapping (Figure 7) (blue indicates motion towards the observer, and red indicates motion away). J'SolEx can accurately measure distances on the solar disk or the diameter of sunspots.

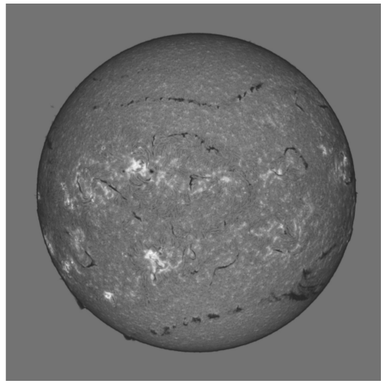

Figure 2. Positive, H-alpha Image of the Sun, July 24.

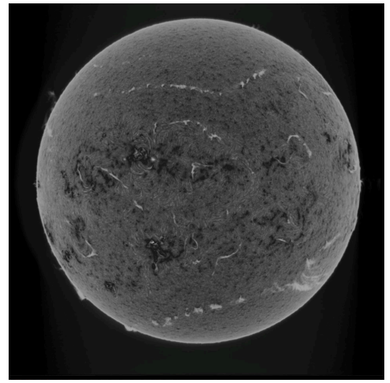

Figure 3. Negative, H-alpha Image of the Sun, July 24.

Discussion

Observations aligned with the solar maximum phase, as indicated by the abundance of prominences and active regions. I was able to achieve my goal of deepening my understanding of spectroscopy and learning to use the equipment and software for this process.

Beyond personal learning, I have used my new knowledge for educational purposes, delivering a demonstration on the spectroheliograph to our astronomy students. H-alpha images are valuable tools for tracking solar activity and can contribute to overall knowledge of the sun's behavior. The instructional guides I wrote will support the astronomical community in developing their own skills.

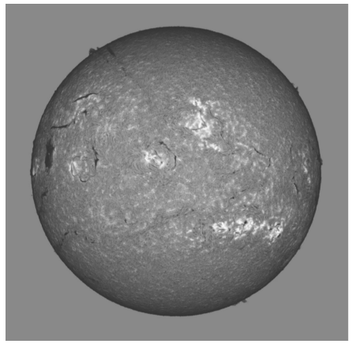

Figure 4. Positive, H-alpha Image of the Sun, July 19.

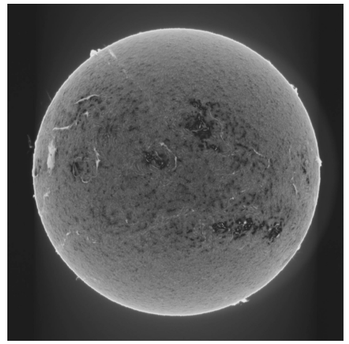

Figure 5. Negative, H-alpha Image of the Sun, July 19.

Conclusion

- Successfully captured and processed H-alpha images of the sun revealing filaments, flares, and granulation characteristics of the solar maximum phase.
- Applied and refined techniques such as focusing and multi-software image processing to produce high-quality images.
- Produced instructional guides on solar spectroscopy techniques, now available through MLAstro and the MLC.

Future work could expand beyond H-alpha imaging to include other wavelengths such as Ca-K (Calcium-K) for a detailed look at the chromosphere and white light for sunspot studies. In addition to this, exploring long-term monitoring of the solar cycle to track changes over time could be a significant project at the MLC.

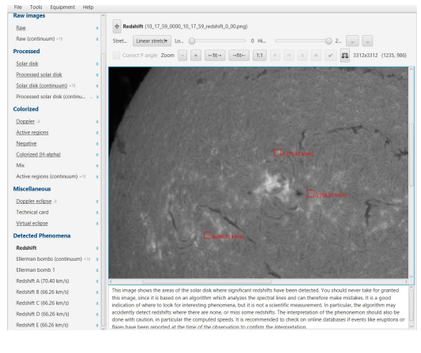

Figure 6. Redshift mapping in J'SolEx.

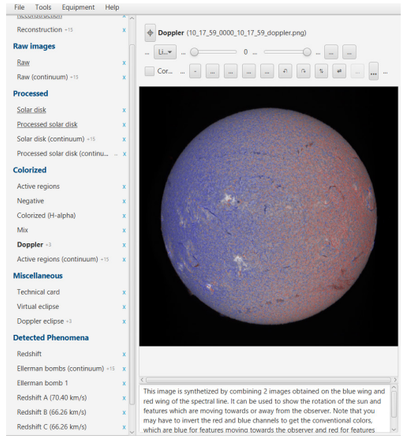

Figure 7. Doppler mapping in J'SolEx.

About the Author

Rebekah Swanson is a junior at Montana State University majoring in Bioengineering with a minor in Biomedical Engineering. Rebekah spent her summer of 2025 working with her mentor, Ryan Hannahoe, at the Montana Learning Center (MLC). She has worked with the MLC since 2021 and was involved in research opportunities with support from the Montana Space Grant Consortium. When not immersed in her studies, she likes to enjoy the natural scenery around Bozeman through hiking and snowboarding. When not outdoors, she enjoys making art in many forms such as painting, sewing, embroidery, and cake decorating.

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The Inescapability of Bad Faith Instances

By Duncan Gentry

Abstract

Jean-Paul Sartre was a French existentialist whose book "Being and Nothingness" is regarded as one of the most influential and important works in contemporary existentialism and in philosophy as a field. The ontology proposed by Sartre is very problematic due to its ambiguous language. In his writings, he expands on what he calls bad faith, a form of deception that prevents the reconciliation of transcendence and facticity. Sartre says that in order to be outside of bad faith, people must begin to live with authenticity; consequently, living in bad faith could constitute living with what he refers to as "sincerity." I agree with a scholar named Ronald Santoni, in which sincerity must be reconfigured to be understood as "living self-consciously of the fact that one is a being which is what it is not and which is not what it is" (Santoni, 159). Simply put, one must configure sincerity to mean living with "honest self-awareness" (Santoni, 159). This reconfiguration prevents equivocation between two meanings of sincerity while preserving Sartrean terminology, but it still maintains that consciousness is susceptible to bad faith. I suggest reflection as a possibility of limiting the physical appearance of bad faith and elaborate on how the 'unreal' instances of bad faith are inescapable, given Sartrean metaphysics.

The Inescapability of Bad Faith Instances

John Paul Sartre was a French existentialist whose book *Being and Nothingness* is one of the most influential and important books regarding contemporary existentialism and philosophy as a field. Yet the ontology proposed by Sartre is problematic due to some ambiguous usage of language. Within his writings, he expands on what he calls bad faith—a way of deception that prevents the reconciling of transcendence and facticity. Sartre says that, to be outside of bad faith, people must begin to live with authenticity. Consequently, living in bad faith could constitute living with what he refers to as "sincerity." I agree with scholar Ronald Santoni, who argues that sincerity must be reconfigured to be understood as "living self-consciously of the fact that one is a being, which is, what it is not and which is not what it is" ("Bad Faith," 159). To simplify his conception, you must configure sincerity to mean that you live with "honest self awareness" ("Bad Faith," 159). This reconfiguration prevents equivocation between two meanings of sincerity while maintaining Sartrean terminology, but it still maintains that consciousness is susceptible to bad faith. I suggest reflection as a possibility of limiting the physical appearance of bad faith, and elaborate on how 'unreal' instances of bad faith are inescapable given Sartrean metaphysics.

I need to define a few terms that Sartre uses to make the reading somewhat accessible; he uses arguably arbitrary idiosyncratic language. Sartre has three conceptions of being that are applied to different aspects of nature and the things that constitute it. First, "being-in-itself" refers to a notion of non-conscious being applied to non-conscious beings, but one key component is that it does not require any negativity or negation. Simply, it just is. "Being-for-itself" is reserved for conscious beings that have the ability to project possibilities into the future; through destruction of the being-in-itself, being-for-itself is contradictory because it is not what it is and is what it is not. The final form of being expanded upon by Sartre is "being-for-others," a being reserved for conscious existence, and that has the understanding or awareness of its relational capabilities as objectionable to other beings. I exist as an object for you; you exist as an object for me. These conceptions of being will allow Sartre to define instances of bad faith. Bad faith for Sartre is the denial of transcendence and facticity.

What are transcendence and facticity? *Transcendence* is strictly attached and associated with being-for-itself because it refers to a projection of the for-itself in future time space. To use an example, transcendence for a free-solo climber is the understanding of the exercise of freedom to such an extent that they can visualize, or imagine, themselves as the being-in-itself as completing the route they attempt to climb. The climber exercises a notion of free will, which is a necessary condition for being-for-itself, and understands that this aspect of his being, the conscious aspect of himself, can freely decide to exist in future moments. *Facticity*, on the other hand, is the string between being-for-itself and being-in-itself. Facticity allows Sartre to justify beings-for-itself's existence *through* being-in-itself, and it could be considered understanding consciousness through existence. Simply, we are what we are. A free solo climber *is* a free solo climber because they wake up and constitute the attributes and perform that role, as restricted to the time space in which they exist. Facticity is completely time-bound and can only exist in a singular time space, whereas transcendence exists both in the present moment and is projected into future moments. The term use exists only with reference to facticity and transcendence in relation to being-in-itself and being-for-itself; these concepts do not *exist* as independent from beingness. They are non-independent concepts.

Consciousness is a fundamental aspect of ontology and needs further explanation. "Consciousness is translucent for Sartre. That is to say, consciousness is aware of itself, consciousness is consciousness of consciousness, it is a non-thetic self-consciousness" (Santoni, "Bad Faith," 151). Sartre and Santoni use *non-thetic* as referring to a conscious experience, but the agent is not currently attending to that experience.

When living in bad faith, the individual denies the reconciliation of facticity and transcendence; the individual acts in such a way that it denies the being-for-itself and reduces action to "existing in the mode of the in-itself" (Sartre, 98). Sartre gives an insensitive example of how someone exists in this mode, and due to apparent lack of sensitivity. I will provide a new example. Continuing with my climbing examples: a climber intends to solo another route in which they know that about a third of the way up there is an opportunity to bail, climb to the side, and give up. On their ascent, they become fatigued faster than anticipated, and when they reach the opportunity to go off route and climb to safety, they deceive themselves into thinking, "*I must finish. I will only be a real soloist if I complete the route.*" In this example, the soloist has denied themself the freedom of continued existence and has perceived their being-for-itself as a being-in-itself. They have treated for-itself as a fixed object in time that cannot be manipulated in future time space by current decisions. By choosing to identify the existence of themself as a soloist and not the essence of themself, they consequently deceive themself that the string that binds transcendence and facticity does not exist. The moment in time in which they decide to continue is when they live in "bad faith." In every instance, bad faith leads to the conscious being denying both a physical and metaphysical freedom that is forced upon them.

Sartre combats living in bad faith with what he calls "authenticity." *Authenticity*, for Sartre, "is that man should be *for himself* and only what he is—in brief, that he should fully and uniquely be what he *is*" (102). This is quite similar to his definition of being-in-itself, so in order to differentiate between the two, he expands further, positing that a sense of being, due to it being an ideal, does not belong in human-reality, and is a synthetic principle. Participating in bad faith requires that "human-reality is not necessarily what it is, and that it can be what it is not" (102). The distinction between being-in-itself and authenticity is that authenticity is actualized and belongs to "human reality." An example of this differentiation could be that authenticity can be self-constituted and actualized whereas being-in-itself cannot project temporally outside of itself. Being-in-itself is being in a non-conscious reality, and authenticity requires consciousness and appears to us through itself. Being-in-itself: A rock is a rock because it is a rock; it is what it is. Authenticity: A conscious being acknowledging the forced freedom and limitations that constitute their reality.

Sartre has a necessary condition for bad faith; he calls it sincerity. One scholar has critiqued Sartre and claims that he has equivocated two meanings of sincerity: one for his own ontological meanings, and one for the everyday usage of the term. "He seems to be juxtaposing an ordinary-language formulation of sincerity with his own idiosyncratic view of human consciousness" (Santoni, "Bad Faith," 155). Sartre could be doing this for a multitude of reasons. He could be taking advantage of the ambiguity to allow for a more coherent ontology, or he is completely unaware of this equivocation. When Sartre equivocates the term sincerity, he is doing it in reference to his conception of being-in-itself and traditional linguistic usage of his definition without explicitly or implicitly identifying the divergence between the two. Sartre defines sincerity as "to be what one is." But according to Santoni,

"The meaning of 'to be what one is' as intended by ordinary language cannot, prior to investigation, be identified with the meaning of that expression when it is used by Sartre technically either to define the in-itself or to characterize an individual's disingenuous move to objectify or 'tie down' human consciousness. Thus, Sartre's conclusions about sincer-

ity are rooted in an ambiguity and depend on an arbitrary, unjustified translation of an ordinary-language characterization of sincerity ("being what [or who] one is") into the pre-established terms and meanings of his technical phenomenological ontology."("Reconsideration," 143)

Santoni provides a solution to this ambiguity if we are to understand sincerity as "Living self-consciously of the fact that one is a 'being which is what it is not and which is not what it is," understanding this simply as "honest self awareness" ("Bad Faith," 159). This reconfiguration of sincerity prevents equivocation from occurring and still maintains honesty to Sartrean ontology.

Consciousness, to Sartre, is a translucent and non-thetic, as described above; consciousness is consciousness of consciousness. When acting in bad faith it appears as a lie, but "the duality of deceiver and deceived is not present here" (Sartre, 90). When lying to someone about something, it implies that the deceiver knows they are deceiving, but during bad faith this duality of knowledge disappears and the essence of bad faith implies "the unity of a single consciousness" (90). This means that bad faith instances do not come from outside forces, but rather from within consciousness itself; consciousness literally *becomes* bad faith. Now, to avoid this trouble, "many people blithely resort to the unconscious" (91). According to Sartre, this is a futile attempt that I will not elaborate on. Continuing, another necessary condition for the *appearance* of bad faith that I believe exists is *action* in a physical sense. Action is not required in the sense of bad faith's "unreal" attributes, but bad faith only *appears* to us as physical action. The reason action cannot be attributed to the unreal attributes is because consciousness constitutes bad faith, and when evaluating consciousness, the moment bad faith appears to consciousness is the moment that bad faith collapses; whereas in reality, the appearance can exist without the attentiveness to it. Thus, if you want to limit the appearance of bad faith, act less and reflect on the action to ensure it was not in bad faith. The unreal aspect of bad faith is consciousness; when trying to prevent individuals' unreal tendencies toward bad faith, the result is infinite regress. Consciousness is consciousness of consciousness; now, when limiting bad faith instances, your consciousness develops into a singular consciousness, and when trying to be conscious of that consciousness, that prior consciousness becomes the former, and the pattern continues. Because it is also a non-thetic property, once you become aware of the "unreal" instance of bad faith, you are no longer within bad faith; but if you are inattentive to the original instance of the conscious aspects of bad faith the current conscious state will digress into infinite regress. You are unable to escape consciousness's tendencies toward bad faith but are able to escape the appearance of bad faith through periods of reflection that dictate your future actions.

About the Author

Duncan Gentry is a Philosophy student at Montana State University, planning to graduate in December of 2026. In his free time, he enjoys being outside, snowboarding, climbing, reading, and being with friends. Duncan hopes to find a job after graduation, so if you know of anyone hiring, please contact him.

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What It Meant to Love You

By Caleb Jackson

Abstract

"What It Meant to Love You" is a short snippet of my longer novella about the relationship between two young adult loners, Joshua and Anna, who find comfort in one another. It is purposefully scatter-brained, much like the characters as they are blinded by nostalgia, love, and lost memories. Although brief, this work is for all those forgotten by those they could never forget.

The Story

To become "great" requires a certain aptitude towards a certain reputation. Joshua Stockwell was not one of these greats.

Joshua eyed the clock on the cream-colored wall, with a scowl across his face as the clock ticked along. Driver's Ed was killing him. Not physically, but Mr. Dolus was ranting about his dead kid, and Joshua wanted anything but to hear it again. It sent shivers down his spine about how casual Dolus could be about something so tragic. Even with the shades pulled up in the second-floor health room, the room always darkened when Dolus' smile faded, as he melancholically stared at the floor. The room was silent as he talked, mindless words filling the students' ears. Some yawned, arms outstretched like lazy cats, while others remained attentive, their beady eyes locked on Dolus like moths to a flame. But to Joshua, most just looked bored out of their flipping minds. Or maybe that was just him. Either way, he raised his hand, drawing a few eyebrows as Dolus quizzically looked over mid-sentence,

"Then he- uh- yes Joshua?"

"May I use the restroom?" Joshua said, already regretting his decision.

"Yeah, after I explain your assignment," Dolus said, his smile aging him by ten years, which, for a bald however-old-he-was, made him look even more like a creepy doll than he already did.

Joshua simply nodded and buried his head in his notebook as Dolus finally moved on to the actual content of the class. With an audible sigh, Joshua twiddled his pencil in his hand and began to draw. He could not care less; he always got good grades.

What was the point of trying? Plus, this character is starting to develop well, Joshua thought as he tweaked the girl's expression from a curled frown to a slight smile. Grunting, Joshua found his left arm had smudged the hair, causing grey to cloud all over her face. Lifting his hand, he saw it covered in pencil lead. He called this phenomenon of being forced to write on a right-handed desk as a leftie the "WWI hand." He could not remember where the term came about, perhaps his love of history, perhaps some random comment by a teacher. Regardless, this third-grader's explanation had stuck for over a decade, and he was not about to let it go.

"Alright, everyone," Dolus said, as his clapping made Joshua wince. "Your project is to create a planned drive to Disneyland in Anaheim, California. I am going to pass out a paper with all the instructions you need, including the restrictions you are under for this planned trip. If you have any questions, please feel free to ask." As people began to shift about as Dolus came around and dropped the assignment off, Joshua simply rolled his eyes.

At least this assignment sounded somewhat entertaining compared to the tests. Gosh forbid, it sounded like heaven compared to watching another hour of those awful 80s and 90s driver "safety tip" videos, he thought as Dolus came around and dropped a sheet off at his desk. As Joshua looked down at the "context," aka, that he was a poor father with two malnourished kids and a barely functioning vehicle, he wondered what father would take their kid to Disney when they obviously had more pressing issues at hand.

Granted, this all came from a few simple words: father, 2 kids, poor, old vehicle. So, what the heck do I know? Joshua thought as he slipped out his garbage-show Chrome computer, which he had won in 8th grade. As he opened a new tab and began to work, he sighed lightly as he glared at his drawing, the grey smudges making it look like she was crying. But even with the smile, Joshua knew they weren't happy tears.

"Anna?" said a tall, blonde-haired woman carrying multiple bags in her hands.

"Yes, mother?" Anna replied, raising her head out of the cage of the rabbit, whose tiny, grey, spotted head was trying to poke out.

"When you are done, can you go and help your sister with the dishes, so we won't be late for church?"

"Yeah, sure, I can do that."

"Thank you."

"Of course," Anna said, a warm smile filling her face.

Anna calmly closed the door to Marshmallow's cage and gazed into his beady black eyes. She saw herself in that reflection, a tiny spec. She chuckled to herself for a moment, then blurted out:

"Wow, I really do look like a guy with short hair."

Perking up quickly, Anna raised her hands to her knees as she locked her eyes on her father as he came into the room, dressed appropriately for the occasion. She smiled to herself as he fiddled with his black tie. Although he frequently buried these types of folks, he clearly still felt uncomfortable embodying aspects of his future, often unwilling, clients. When he cut his pepper-flecked beard, he looked like a younger man, but those wrinkles around his eyes betrayed the weariness of three kids. Anna was glad she would never have any children. Just as soon as he appeared, he disappeared upstairs, softly gliding up like a phantom as he muttered about "preparations."

Anna chuckled, "Alright Marshmallow, I better get ready."

Marshmallow stared at her and squeaked.

Anna sighed, "You had enough to eat Marshmallow, soon enough you'll be as round as one."

Glancing up at the clock, Anna smiled sadly as she walked her way to the kitchen.

Another day of church, Anna thought. *What possibly could go wrong?*

Have you ever wondered what it would be like to remember everything? he thought to himself as he rounded the corner to the front of the school. The snow crumbled around him as he walked towards the sign that read *Fate High School* in big bright yellow and black lettering.

Below, they had the oh-so-obvious, yet stupid slogan: *Fate is Great!* It wasn't, at least for today.

As Joshua stood there next to the ten-foot sign, the wind whipped about him and sent a shiver down his spine. With only a T-shirt and jeans, he should have worn a jacket, but nope. He felt the prickles of cold spreading across his body, but stood as still as a statue as he waited for his grandmother. He breathed into his hands, the CO_2 billowing out and right back into his face as the wind played its cruel tricks around him. Checking his phone, it was a causal -10 degrees Fahrenheit, or -23 Celsius for the layman. As he waited, his mind wandered towards his environment.

The suburban sprawl was a bother, though not as much as the nursing home that felt like a proto-cemetery. At least once a week, there would be an ambulance rushing towards the place and paramedics lifting a bag into their vehicle. One day, Joshua just knew, whether it be from intuition, nihilism, or his plain old gut, he knew he was going to be there sooner rather than later. He grimaced as he heard sirens growing in the distance.

Two Days Later

"Hey, I was wondering if you, maybe, I don't know, would like to go to prom with me? As a friend, of course," Joshua quickly added, tension and sweat consuming his body while Anna could do nothing but smile with infinite warmth.

"Well, that was a mess, I can understand if you don't wanna now," Joshua said with a laugh.

"Haha, no, no, I want to go with you, it sounds lovely," she said, genuine sincerity flowing from her voice.

"Really? Wow. Okay then!" Joshua exclaimed, butterflies filling his chest as he caught a twinkle in her grey eyes.

"Guess we will have to plan something then for outfits!" Anna said. "But I gotta go now, Marshmallow needs dinner!"

"When doesn't he?" Joshua snickered.

He closed his eyes as Anna's laugh filled his ears and the tension in his body deflated.

A smile crossed his face as he replied, "Well, I guess I'll let you go. Talk to ya later, Anna?"

"For sure! Later Josh!" Anna replied as she turned and strolled up the stairs.

"Byeeeeeeeeee!" Joshua said, waving towards Anna while he walked backward, miraculously not tripping. As he lost sight of her, he gently sighed.

He was an idiot, but gosh did he want to be her idiot.

Explication

Friendship and love have a long history, most famously outlined in *Nicomachean Ethics*, where he describes friendship as encompassing the vital components of utility, pleasure, and virtue for a happy life (eudaimonia).[1] Throughout the centuries, Aristotle's work has been accepted and tested, but the philosophy scholar Mark Phelan argues for expanding the term "friendship" to include "lesser friends," as friendships are the "product of significant collaborative norm manipulation."[2] *What It Meant to Love You* takes this presumption that friendships are the product of norm manipulation and runs with it, exploring friendship between members of the opposite sex and the implicit expectations placed on the individuals (i.e., Joshua and Anna) by themselves and society.

One of these expectations is the perception of a friend-to-romantic-partner pipeline. For example, in one study, around 68 percent of adults had been friends before becoming romantic partners.[3] In fact, much of the initial formation of friendships tends to be shaped by criteria such as physical appearance, economic status, and physical presence, with men tending to focus on appearance, and women on the latter two.[4] It is a progressive timescale, from strangers to partners. One potential consequence of that perception is that any friends of the opposite sex *must* have romantic feelings for one another. Studies continue to assert that "Romantic and sexual desire for an opposite-sex friend is common," in which one individual's projection of their desires onto their friend "may motivate people to take a leap of faith and pursue a romantic relationship."[5]

In *What It Meant to Love You*, the character of Joshua helps explore these perceptions and projections. His scenes provide insight into his worldview, specifically his reinforcement of a negative thought process and his sense that life is seemingly meaningless. For example, in the story, Joshua is listening to Dolus, the Driver's Ed instructor, talk about his dead son. Joshua, out of boredom, asks to use the restroom to get Dolus back on track to the class. Yet, even with that effort to avoid a perhaps uncomfortable topic, he audibly sighs, as "He couldn't care less; he always got good grades. What was the point of trying?" Joshua continues that with the nursing home scene, where he states that "One day, Joshua just knew, whether it be from intuition, nihilism, or his plain old gut, he knew he was going to be there [dead] sooner rather than later." As one can note, the society around Joshua really shapes his attitude, whether it be the boring and uncomfortable stories from Dolus, or just the physical presence of a nursing home and its implications, Joshua's mind locks onto those negative aspects of his life, which leads to a self-repeating cycle of seeming meaninglessness.

Yet, we see how this is ultimately changed when he is around Anna. As exhibited through the last line of the story, after Joshua successfully asked Anna out to prom, he thinks to himself about how "He was an idiot, but gosh did he want to be her idiot." In this line, there is a powerful indicator of how Joshua is projecting his feelings onto Anna. Because she said yes to his offer, Joshua is now considering developing a romantic relationship with Anna, whereas in all the other scenes, he did not think about her at all. A societal circumstance of prom and the expectation that you need someone to go with drives Joshua to ask Anna out, and in turn, that societal pressure makes Joshua fall in love.

Although brief and scattered, *What It Meant to Love You* is not just another short story but the beginning of a deeper narrative about love and how it develops and is challenged in the context of friendship. Exhibited primarily through Joshua's character, the perception and projection of love onto Anna, his opposite-sex friend, showcases how expectations and norm manipulation can dramatically shift an individual's perception of others. Any further additions to the story would analyze the societal impacts on Joshua and Anna's friendship, specifically the pressure to become a romantic couple and the tension that arises when one of the pair does not feel the same way. Overall, though, *What It Meant to Love You* goes to show how love and friendship are far more complicated and deserve much more investigation than they have been given.

About the Author

Caleb Jackson is a senior in the History-Teaching program at Montana State University. Academically, Caleb has worked with the McNair program to research the intersections between creative fiction and its cultural themes throughout time. In his spare time, Caleb is an avid hiker and writer who plans on publishing a book in the near future. After pursuing his bachelor's, Caleb plans to take a few years to travel before settling down in a rural Montana town for his foreseeable future.

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At Montana State University, undergraduate research is not an accessory to the educational experience; it's central to who we are as a land-grant institution. Through their curiosity, creativity, and commitment to real-world impact, our students strengthen communities across Montana and beyond. Curiositas is a reflection of those efforts. It showcases not only the excellence of MSU students but also their drive to ask the meaningful questions and pursue the answers that matter. I am proud of the work represented in these pages and grateful to all who contribute to this important publication.

Brock F. Tessman
President, Montana State University

Photo by: Jonni SpottedEagle

Iiinnii (bison) herd in Paahtómahksikimi/Waterton Lakes National Park in Alberta, Canada, cross the border from Glacier National Park and Blackfeet Nation.