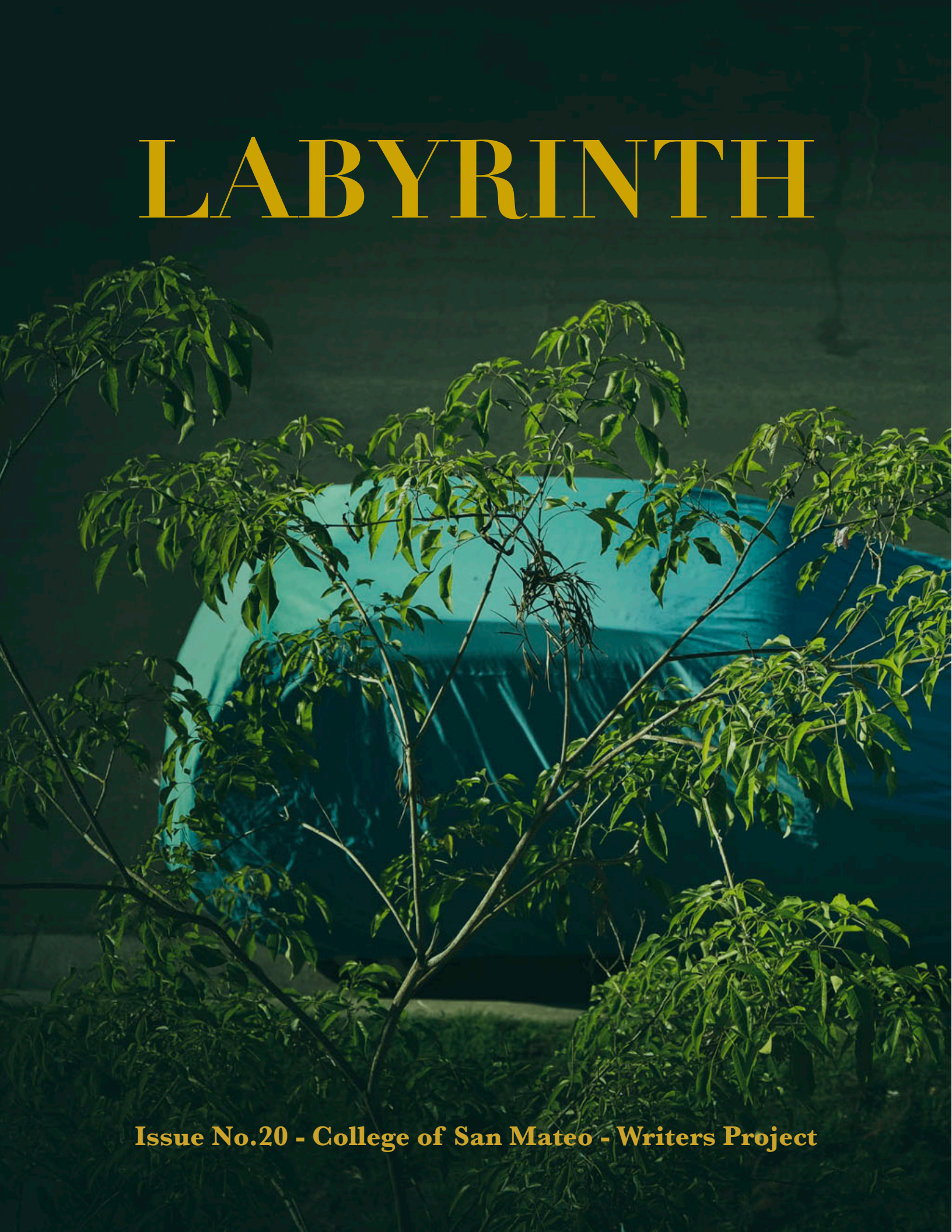
LABYRINTH



Issue No.20 - College of San Mateo - Writers Project

Cover Photo: Still Life by Maria-Gracia Inglessis

The Writers Project and Labyrinth staff
would like to extend our sincere thanks to:

The CSM Honors Project faculty, staff, and students, with special thanks to David Laderman, for their continued support of our club and our vision,

our inspiring club advisor, Sarah Mangin.

and the students who submitted their work to be considered for this publication.

We want to thank you for reading our new issue of Labyrinth and hope that this publication continues to inspire you.

Keep writing. Keep learning. Keep creating.

Labyrinth Issue 20

Friday Afternoon Press

writersprojectsubmissions@gmail.com

CONTENTS

CONTRIBUTORS

Editor-in-Chiefs

Angel Perez Garcia

Maryuri Aguilar Aguilar

Design Director

Chloe De Leon

Advisor

Sarah Mangin

Editorial

Abi Navarro

Charlesmore Largo

Daniela Ruiz

Natalia Castillo

Shiloh Gomez

ICC Representative

Jenifer Olayo

Letter From the Editors

As editors, we are honored to introduce the 20th edition of Labyrinth. While this publication has always been a home for academic excellence and creativity, this year it has become an essential space for intellectual and emotional discussion. Despite the challenges of this semester, we are moved by the quality of the student work. These pieces refuse to stay silent, choosing instead to explore the deep complexities of the human experience.

We release this issue during a time of rising anti-immigrant rhetoric that targets our communities. We believe it is more important than ever to use our voices to challenge unfair institutions and hold them accountable. Our education is a privilege that has taught us to question; for how can we seek to grow as a society if we do not question the efficacy of our institutions and actively work to bridge the gaps they leave behind? By sharing these stories and artworks, we hope to encourage a spirit of resistance and a constant demand for justice and inclusion. Students often do not realize how much power their voice holds, especially together, as an institution holds no power without a student body.

Issue No.20, a publication for the spring 2026 semester, investigates the three primary concepts: Transcendence, Chromaticity, and Desire. Transcendence explores the movement beyond conventional boundaries, looking at how experiences can allow us to surpass our perceived notions. Chromaticity analyzes the psychological and physiological impact of the visual spectrum, exploring how color and intensity construct our perception of reality. Desire explores the fundamental impulses that range from intellectual ambition to interpersonal longing that aid in human agency and define the psyche. We present this issue with the hope that students remain committed to acts of creative inquiry, pedagogical growth, and critical engagement with the world.

In Community,
Angel Perez Garcia & Maryuri Aguilar Aguilar

Into the Labyrinth

David Laderman

Recently I had the opportunity to sit in on a Writers Project club meeting, covering for faculty adviser Sarah, who couldn't make it. It had been a long time, and I could feel the joy and inspiration rising through me, listening and observing, as the students tried to decide on the next Labyrinth cover--thinking to myself, wow, this right here, this is what I'm really going to miss, this hanging out with these bright young people…

Right on cue, reading the room in my mind, Natalia timidly inquired with me, whether it's true, that I'm retiring this semester. I mumbled a bit, my usual evasive and tentative equivocations. Always feeling possessed by multiple perspectives on any one thing, however certain and stable it may (pretend to) be, distancing myself from my very reply, which was--yes, it's true. And then, Natalia inviting me, or more like gently coaxing, to submit something reflective, for the upcoming issue, about my years working with Labyrinth and the WP club. Full of unassuming grace, she assured me that whatever and however it was, she and the team would find a way to make it work.

This in turn (of course) lead me further down the rabbit hole of meta-(self)reflection: wanting to be able and inspired to write, during retirement. Not sure what, but something, anything; trembling yet drawn onward by that undertow. How her solicitation reverberated with so much of my own anxious enthusiasm, enthusiastic anxiety, about entering this new chapter of my life. And the daunting yet alluring prospect of starting somehow, to write it ("I'm still getting educated but I've got to write it down"). I thank her for her warmth and intuition. Here we are now.

During the meeting, we stumbled ("stumbled" but, for me, no accident) into a brief chat about the name "Labyrinth" – how it came to be, what it actually means, and how the spelling is so enigmatically peculiar, how it doesn't really seem like it should be spelled that way. Shouldn't it be "labrynth"? Or even "Labrinth," as Euphoria's former music composer spells his stage name (apprised coincidentally by my students, and son, while writing this—so, here it is).

In the beginning, circa 2013, Labyrinth emerged as an Honors Project student newsletter (in tandem with a labyrinth icon as program logo); then morphed, under the sway of the students at the time, into the more robust and sophisticated student academic journal we know today, devoted to poetry, essays, fiction, artwork of all varieties, along with diverse academic pieces.

We briefly unpacked a few meanings and connotations: a structure, a trope, a Greek myth (the one with that cool but nasty Minotaur dude), a tangled web, a disorienting network of hallways and passages (and, in my mind, those scenes from The Shining). But mostly, for us, this: a challenging maze, to find your way through, and out of. This seemed so perfect, for the moment, but also for the club, the magazine, the Honors Project, along with my encroaching retirement, and so much about CSM: finding your way out, and (therefore?) into yourself; finding your way through minefields, sundry snags and maelstroms, so as to express and fulfill yourself—creatively, intellectually, soulfully.

Such fervent labor coming to fruition is evidenced by all the top national honors newsletter and magazine awards Labyrinth has garnered over the years. But also and more so, evidenced by the words and images themselves – holding each new issue in your hands, skimming through it, getting lost in there, this was always a redemptive experience for me—a fresh breath of fresh air. I always kinda couldn't believe it. But, I could--knowing the students who chiseled it into being.

This then is the gist of the role I served, a kind of vessel, a clumsy if manic assistant Hollywood producer, behind the scenes, on the sidelines, scrambling to help the students get what they needed—whatever it was—so they could bring Labyrinth forth. Put differently, it was all a precious gift of facilitation, of bearing witness: all the intense hours, conversations, meetings, editing, promotion, and the miraculous final product—all of that, truly, came from the students. It's all theirs. Theirs, and the faculty advisors, always on hand to lend a hand, hashing it out, mashing it up.

I think back on all the visionary stewards, the student chief editors—let me sing their praises by singing out their names electric: Dee Dee, Mondana, Kelly, Gabriela, Candela, Ariana and Maya, Umit, Lesieli, Aki, Erika, Angel and Maryuri. And the faculty advisors too, prime humans we're so lucky to have danced with: Tim (the labyrinth lift-off OG), Jill, Mitchell, Keira, Sarah.

(Sidenote: do yourself a favor, bounce through some back issues, posted here: https://collegeofsanmateo.edu/honorsproject/thelabyrinth.asp)

Winding down, zooming out: my years riding the Labyrinth tide seem very clearly to me an emblematic sliver of my larger and more replete journey here at CSM. Being able to teach film (my beloved career passion, my rabbinical calling) for so many years, to so many incredible students, across so many fascinating cinematic landscapes; and later, being able to also serve as faculty coordinator for the Honors Project—well, it was all simply a grand blessing, a guiding gem. Keeping me buzzed, in the sacred groove, head-spinning, working and playing alongside lit students maximizing their intellectual and artistic pursuits. And such fantastic support, input and interactions with my dear colleagues, forging an empathetic turbine tapestry for our burgeoning scholars—all the while, blown away by them—this too has been another vital layer.

I'm deeply grateful to my students, for teaching me, so much; for following my leads and for leading me into countless surprising and unknown places. Into the Labyrinth. Where I now fully realize I'll always want to be.

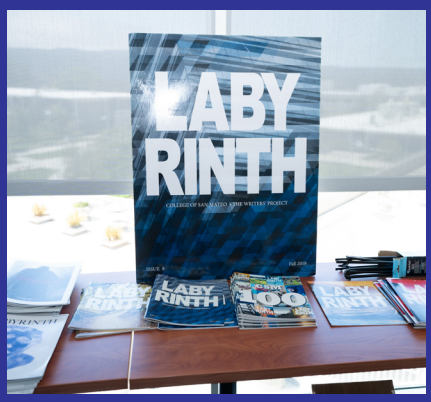


Photo: *Light and Shadow 1* by Albert Lau

Keystone: Path to Ecological Recovery-Exploring Environmental Decline and Biotechnology's Viability in Conservation

Charlesmore P. Largo

Abstract

With the alarming rate of biodiversity decline, our world is left vulnerable to the growing pressures perpetuating it. The overall health of an ecosystem relies on the combined strength and resilience of these factors, and when one becomes compromised, the other follows into a negative downward spiral. Due to the external factors that come from human activities, our environment is degrading. Along with it are the animals that inhabit them, who are also experiencing negative effects for the same reasons. To address the decline in biodiversity, the option of biotechnology is an option to be explored. This technology holds the potential to solve biological issues like endangerment and extinction. They remain inefficient and risky, although traditional conservation carries risks as well; biotechnology remains promising for future viable use. The real issues come back to the environments that have been heavily and unnaturally altered in a way that they cannot sustain species anymore. Even with the success of biotechnology and other animal-oriented efforts of bringing them back, without the foundation of the ecosystems they inhabit, sustaining them in a meaningful way long term, everything will still end in failure.

Introduction

Extinction is part of the Earth's natural process. Like a cycle, it's a recurring event that naturally occurs in pans thousands to Millions of years. But what makes things different in the modern day? Today, we rival extinction rates from major historical extinction events in a fraction of the time in which they naturally occur. This decline not only poses a threat to the creatures among us but also to daily human activities. Through the loss of species and environmental degradation, things can exponentially spiral out of control. Since traditional conservation methods struggle to keep up with biodiversity decline, we should consider alternative approaches that can help mitigate some of the limitations they face. I became interested in this topic because of the viral news in April 2025, when Colossal Biosciences announced the de-extinction and birth of dire wolf pups. The possibility of reviving a species that has been lost for thousands of years is scientifically revolutionary, but it immediately raised a critical question for me. Is the best application of this powerful technology resurrecting long-extinct animals that may lack a viable, modern habitat? I believe the true value of cloning and genetic engineering of animals comes from applying these tools to save species on the immediate brink of extinction or to restore those that are functionally extinct from ecosystems that still desperately need them. To combat the accelerating loss of biodiversity, biotechnology, ethically guided cloning, and genetic engineering can be a viable and necessary complement to traditional conservation, offering means to restore genetic diversity and reproductive viability to reestablish ecosystem balance and prevent ecosystem collapse.

Background:

The global biodiversity decline is a crisis driven by human activities. Earth's ecosystems are like an intricate network of interconnected structures, and when these networks start to fail, a sort of domino effect results in widespread collapse of these structures. There are five major human-induced pressures acting in tandem, eroding the planet's biological resilience (Hald-Mortensen, 2023). The central crisis stems from converting natural habitats for human use. This involves replacing ecosystems that host diverse life, like forests and wetlands, with monocultures or urban areas, which not only destroys habitats but also fragments the remnants of them. At the same time, urbanization introduces massive amounts of pollution, including industrial waste, agricultural runoff, and plastic that poisons water, creates dead zones, and slowly degrades the environment. Compounding this physical destruction are the resulting volatile temperature changes. With the weakening of natural regulators and excessive greenhouse gas emissions heating oceans, causing acidification, and creating generally volatile and unpredictable weather patterns, species are rapidly forced beyond their capacity to adapt (Hald-Mortensen, 2023; Rafferty, 2025). Resource exploitation, such as overfishing, also rapidly depletes ocean life and other exploitative uses of nature, destroying food webs as they struggle to replenish enough in population or resources to remain stable, adding to the already unstable state of the environment. Finally, global trade acts as a vector for invasive species. These organisms arrive in new habitats without natural predators, quickly outcompeting native life, spreading disease, and fundamentally altering ecological balances. Together, these pressures create inhospitable environments. They affect ecological markers for species and their natural cycles, disrupting essential functions such as breeding and feeding patterns that can have a larger effect on the environment by depriving food webs of essential elements (Rafferty, 2025). With environments degraded and resources dwindling, there will be tough competition, and there won't be enough to sustain a healthy number of organisms in an ecosystem, diminishing its carrying capacity(the maximum amount of species an ecosystem can sustain for an indefinite length of time). Not to mention some of these factors that are causing genetic bottlenecks, such as habitat fragmentation isolating populations, while environmental instability increases stress. This combination depletes the genetic diversity necessary to resist disease and adapt to new conditions. Ultimately, survival relies on maintaining enough genetic "resilience" to sustain the population over future generations; without it, extinction becomes increasingly likely (Rafferty, 2025).

Keystone species, originally introduced by Paine (1969), is a notably crucial member of an ecosystem. The term refers to an organism whose functional impact on its community is disproportionately large relative to its size (Power et al., 1996). The loss of such a species can trigger a "dramatic shift" in the ecosystem, leading to instability or collapse, much like the removal of a keystone causes an arch to fail. Keystone species influence structure through various mechanisms, including predation, habitat modification, and supporting crucial mutualistic relationships (Power et al., 1996). The functional importance of keystone species extends into valuable ecosystem services that directly benefit global regulatory systems and human society. For instance, predatory keystone species contribute significantly to natural pest control, fostering more sustainable resource management by reducing the reliance on chemical interventions in agriculture. These important species have so much influence on their local ecosystems that a threat to their habitat and stability results in a greater threat to their whole ecosystem as a whole (Power et al., 1996). Affecting not only themselves but also cascading down negatively to other species, this is why it is imperative that they are safeguarded and kept at high population levels, which is the best defence against collapse. The strong, steady presence of these keystone species indicates a resilient ecosystem that preserves its general health and functionality even in the face of external pressures.

Combating these ecological issues requires conservation strategies that rely on the complementary strategies of in situ and ex situ management (IUCN SSC, 2016). In situ (on-site) conservation is the foundational approach, focusing on protecting species within their natural habitats to preserve essential ecological processes, such

as trophic cascades and natural evolutionary dynamics (Power et al., 1996; Svenning et al., 2016). Effective in situ efforts directly counteract the primary drivers of biodiversity loss, including habitat destruction and climate change (Rafferty, 2025). However, when wild populations suffer severe decline, ex situ (off-site) conservation becomes crucial, safeguarding genetic material in controlled settings such as zoos and biobanks.

When it comes to ex-situ conservation, a crucial direction that can be explored would be biotechnology, which has progressed from Somatic Cell Nuclear Transfer (SCNT) to advanced gene editing. SCNT, demonstrated by the 1996 cloning of Dolly the Sheep, proved that adult cell nuclei could be reprogrammed to direct development (Wilmut et al., 1997), successfully reintroducing lost genetic variation. However, SCNT is inherently inefficient and prone to developmental defects like Large Offspring Syndrome (LOS) due to incomplete reprogramming (The Humane Society of the United States, 2006). The success of both SCNT and subsequent genetic editing tools fundamentally relies on biobanking, which provides the ethically sourced, quality-controlled, and expertly managed biospecimens (such as, cells, tissues, nucleic acids) and associated data essential for these complex genetic procedures (Annaratone et al., 2021). These high-quality samples are especially useful with the adoption of precision tools like CRISPR-Cas9, which allows for Targeted Genetic Intervention (TGI) (Kosch, 2022). TGI is critical for helping threatened species adapt to modern challenges, with applications ranging from engineering blight resistance in the American Chestnut to de-extinction efforts like conferring cold tolerance to the Asian elephant for the Woolly Mammoth project (Colossal Biosciences, n.d.-a).

Literature Review

The global reliance on traditional conservation methods is proving insufficient to counter accelerating, human-induced biodiversity loss (Hald-Mortensen, 2023). As species populations fragment and adaptive genetic variation is diminished, advanced biotechnology offers a new direction in conservation. SCNT is primarily a tool for genetic rescue, reintegrating lost genetic variation into critically endangered populations (Hald-Mortensen, 2023; Kosch, 2022; Martinelli, 2024) via ex-situ biobanking. The black-footed ferret cloning, which integrated lost genetics into the endangered population and produced viable offspring in 2024, confirmed this strategy's success (U.S. Fish and Wildlife Service, 2024). Similarly, genetic engineering (GE), leveraging work in livestock, can use CRISPR-Cas systems to introduce adaptive traits, such as disease or climate resistance, proactively enhancing a species' survival against existential threats where natural adaptation is too slow (Kosch, 2022).

Currently, a lot of the progress for large-mammal genetic technology is driven by private firms that frame their work as a business of discovery. This venture capital approach relies on a dual-use Research and Development (R&D) model aimed at generating high-value Intellectual Property (IP). De-extinction projects, such as the Woolly Mammoth initiative, function as R&D platforms where breakthroughs are intended to be repurposed into lucrative biomedical spin-offs(Colossal Biosciences, n.d.-b). This commercial framework introduces a selection bias, prioritizing megafauna that promise the greatest IP over species whose ecological importance might be higher. While the venture-capital approach currently driving the Woolly Mammoth project introduces a commercial bias, the underlying justification extends beyond Intellectual Property (IP). The mammoth's potential to restore a missing keystone ecological function provides a significant modern-day benefit. Furthermore, the research platform itself accelerates the development of advanced tools, like gene editing and cloning, that can be directly applied to provide genetic diversity and disease resistance to struggling, currently endangered species. This remains vital as SCNT remains inefficient, with viable live birth offspring rates between 1–5% (The Humane Society of the United States, 2006). This systemic issue persists in complex GE, with survival rates as low as 1.5% in some modified livestock (The Humane Society of the United States, 2006). Thus, the general development of these technologies would be beneficial at this point; however, a direction towards the greater cause of conservation would be of even greater benefit, as it avoids commercial biases.

With this technology, reintroduction of lost genetic variation to improve genetic diversity for declining populations would protect them from abrupt pathogenic threats or decline. Such is what was observed in the black-footed ferret's cloning and successful breeding of those clones. The clones of a black-footed ferret that lived in the 80s, whose samples contained 3 times the current endangered population's genetic diversity, had offspring that are currently growing healthy (U.S. Fish and Wildlife Service, 2024). The reintroduction of this lost genetic variation to the current endangered population would only help boost its resilience, especially in terms of long-term growth. The evidence demonstrates that biotechnology possesses the specific technical means to bypass genetic hurdles faced by traditional conservation, such as narrow gene pools and the slow rate of natural adaptation. Somatic Cell Nuclear Transfer (SCNT) is able to circumvent a genetic bottleneck by recovering and reintroducing lost genetic material from decades-old biobanks, as demonstrated by the successful breeding of the black-footed ferret clone, Antonia (U.S. Fish and Wildlife Service, 2024). A capability that traditional conservation breeding could never achieve. Furthermore, Targeted Genetic Intervention (TGI) bypasses the slow process of natural selection by introducing adaptive traits, such as disease or thermal resistance, into a species' genome in a single generation (Kosch, 2022).

For the goal of restoring lost ecological function, the concept of reintroducing a genetically modified organism must be considered against the scientifically proven alternative, such as ecological substitution (Svenning et al., 2016). Ecological substitution, a core component of trophic rewilding, advocates for the reintroduction of an ecologically analogous species to occupy the extinct species' niche, thereby restoring ecosystem balance using existing, low-risk organisms (Svenning et al., 2016). If a keystone herbivore is lost, reintroducing a functionally similar species, such as an African ostrich to fill a specific grazing/seed dispersal niche, is simpler and presents significantly lower ecological risk than genetically engineering a proxy species (Svenning et al., 2016).

With biotechnology addressing genetic hurdles, traditional reintroduction projects adopting the proxy species method provide the operational blueprint. The success of this method, or if biotechnology is used, hinges on the identification and removal of the limiting factor that caused the decline in the ecosystem. The reintroduction of grey wolves, a keystone species to Yellowstone National Park, exemplifies the benefit of restoring a keystone species (Paine, 1969; Power et al., 1996). The return of this apex predator initiated a trophic cascade, suppressing browsing by elk and allowing riparian plant communities to recover, which in turn benefitted the beaver population (Farquhar, 2025). Before 1995, elk populations had pushed the limits of the park's carrying capacity, browsing heavily on young willow and aspen stands during winter. However, the return of wolves forced elk to become more vigilant, break into smaller herds, and move into heavy timber (Farquhar, 2025). This behavioural shift relieved the grazing pressure on riparian vegetation, allowing willow stem biomass to recover to ten times that of browsed plants (Farquhar, 2025). This recovery of vegetation triggered a secondary wave of ecological restoration, most notably for the beaver population, another keystone species. With robust willow stands available for food and dam construction, Yellowstone's beaver population expanded from a single colony in 1995 to nine colonies today (Farquhar, 2025). These beaver dams have subsequently improved the park's hydrology, storing water to recharge

the water table and providing cold, shaded habitats for fish and songbirds. Furthermore, the wolves now function as "food distributors" for the broader ecosystem. Unlike the previous years, where carrion was only available during harsh winters, wolf kills provide a steady source of food year-round, supporting a vast web of scavengers, including ravens, eagles, and grizzly bears (Farquhar, 2025). This confirms that while the specific effects were complex, the restoration of a crucial keystone species successfully helped stabilized the entire ecosystem.

Discussion

The outcome from Yellowstone proves that the reintroduction of healthy animals(clone, genetically engineered or substitute) would do good for the restoration of an ecosystem. However, this was only part of the problem, as we must address the ecological and social failures that caused them in the first place. Biotechnology addresses specific functional or genetic losses (Kosch, 2022). GE can fortify populations against threats like disease. For de-extinction, the goal is restoring lost keystone functional roles (Colossal Biosciences, n.d.-a). However, this utility is limited if the habitat is "irreversibly degraded," risking failure of the revived animal to perform its historical role or potentially acting invasively (Colossal Biosciences, n.d.-a). This puts a heavy emphasis on the factors contributing to the decline of our environment. In the case of the Yellowstone wolves, years of predator hunting initiatives followed the westward expansion in an attempt to protect livestock (National Park Service, 2025). Wolves in general became endangered in the country as a whole, but their complete disappearance in Yellowstone is what makes things alarming, as an essential part of the ecosystem's functions has left a role in the food web completely unoccupied.

Additionally, successful integration must adhere to guidelines, including standardized Disease Risk Analysis (DRA) and clear "exit strategies" (IUCN SSC, 2016). The assessment of risks versus benefits in biotechnological restoration is a high-stakes trade-off, balancing species integrity against the potential prevention of permanent biodiversity loss. The primary benefit, preventing the final, permanent loss of adaptive genetic variation and potentially restoring vital keystone functions, is enormous (Hald-Mortensen, 2023; Power et al., 1996). If de-extinction efforts, like the Woolly Mammoth proxy, successfully restore a lost ecosystem engineer, the benefit could be global climate mitigation (Colossal Biosciences, n.d.-a). The primary risk is ecological mismatch, the high probability that a revived organism will fail to integrate ecologically or may act invasively in today's altered ecosystems (Colossal Biosciences, n.d.-a).

This, however, is only part of the bigger picture because, as successful as it was, even the Yellowstone wolf reintroduction has its issues, which exposed a critical oversight in disease dynamics. Almberg et al. (2012) demonstrate that the reintroduced wolves, having been medically isolated, lacked herd immunity and suffered immediate, catastrophic pathogen "spillover" from local coyotes. Within a single year, 100% of sampled wolves contracted Canine Parvovirus, while outbreaks of Canine Distemper Virus later caused pup mortality rates as high as 90% in the Northern Range. Furthermore, the high wolf density in prime habitats created an "ecological trap" that facilitated the rapid spread of Sarcoptic mange, leading to the total wiping out of specific packs (Almberg et al., 2012). This reveals that reintroduction can create populations that are not fully analogous and that experiences chronically destabilization by disease. Aside from this, threats of proxy species, deviating from the exact niche the original species occupied, can create extra competition for other resources and create other ecological issues down the line.

The same can be said for engineered specimens that may stray from their intended purpose and habitats. Those concerns can create a different issue of invasive species that can potentially outcompete local fauna. The most extreme risk is posed by self-propagating CRISPR-based gene drive systems, which are scientifically deemed "highly invasive" and "likely equivalent to creating a new, highly invasive species" (Esvelt & Gemmell, 2017). This demands strict containment and regulatory oversight (IUCN SSC, 2016). The high animal welfare concerns suggest that clones be maintained in managed facilities, serving as genetic banking assets rather than immediate candidates for restoration, as was observed with the black-footed ferrets. The viability of cloning relies heavily on the second-generation hypothesis. This is the hope that first-generation abnormalities do not transfer to naturally bred offspring, justifying the welfare cost for the resultant genetic diversity (Kosch, 2022). On top of these current biotechnological challenges, the same issues are present in these tools, just as they are in the more natural proxy species. Having a compounding number of problems reveals that, currently, biotechnology should be defined as a last-resort, specialized genetic tool in conservation, not a primary strategy that replaces traditional in-situ habitat restoration. The best application of these technologies for now is the defensive use of Targeted Genetic Intervention (TGI) to fortify existing populations against threats that cannot be mitigated by other means (Kosch, 2022). SCNT should be reserved for genetic rescue when a species is at the absolute brink. As this process takes time, genetic rescue for urgent instances would not be very viable. However, for long-term efforts, it proves to be useful. This, however, is only the beginning of these technologies, as a lot of the issues, specifically in SCNT, show promise of progress, especially in vitro, as demonstrated in French et al. (2006), where in vitro produced specimens of clones show a much higher and consistent survival rates overtime.

Beyond the advancements of these technologies themselves, global conservation must prioritize in-situ preservation and habitat restoration, as habitat loss, exploitation and pollution are the dominant drivers of decline (Hald-Mortensen, 2023). However, ex-situ measures (captive breeding, biobanking) are essential for mitigating the extinction of adaptive genetic variation and supplement primary biotechnological tools(Hald-Mortensen, 2023). While the ethical implications concerning animal welfare are significant, stemming from the high morbidity in the first generation of clones (The Humane Society of the United States, 2006), the utility of these technologies cannot be overlooked. The development of these technologies, especially as the threats to the environment and the creatures living in it persist, could transform them into a more plausible and reliable avenue of ex-situ conservation (Martinelli, 2024). Ultimately, the future role of biotechnology is thus to serve as a vessel of genetic viability, but the decision to reintroduce, however, current applications should be limited and be done under extreme caution to avoid the catastrophic risks it brings.

Conclusion

In essence, as a potent, although specialized, tool in the contemporary conservation toolbox, biotechnology has great potential. Tools like SCNT and CRISPR can offer a vital lifeline for animals on the verge of extinction by providing a way to restore genetic variety when natural options are exhausted, as evidenced by the genetic rescue of the black-footed ferret. Nevertheless, neither "natural" alternatives like trophic rewilding using proxy species nor high-tech ones provide a perfect solution. But both strategies have serious flaws. Proxy reintroductions, like the Yellowstone wolves, might result in "ecological traps" that are unstable due to sickness and unanticipated competitive exclusion, while biotechnology suffers from inefficiency, ethical issues, and a wide array of other considerations to ensure success or, at the very least, prevent any more damage to the ecosystems. Our capacity to artificially construct ecological stability is seriously threatened by these intrinsic defects, yet this only tells us that there is more to do in order to equip these methods in our conservation toolkit.

Therefore, it would benefit the scientific community to continue rigorous Research and Development (R&D) in the field of biotechnologies. Refining these tools will arguably be essential for the long-term battle against environmental degradation, providing humanity with the capacity to intervene when natural recovery is no longer possible. However, we must recognize that these high-tech interventions are ultimately reactive measures and attempts to fix a system that is already broken. We would benefit even more if we shifted our primary focus from resurrection to prevention. The most effective conservation strategy lies in aggressively combating the five major drivers of environmental decline, which are land-use change, climate change, marine exploitation, pollution, and the spread of invasive species. These are the pervasive factors negatively affecting our ecosystems in the first place, and by prioritizing the prevention of these pressures and working to reverse their effects through habitat restoration, we attack the root of the crisis rather than merely treating the symptoms. Ultimately, while we must sharpen our biotechnological tools for the future, our immediate action must be to heal the ecosystems we currently have, ensuring that the need for genetic rescue becomes an option rather than a need. In this way, we are helping to improve and sustain the living world that we live in.

Works Cited

Colossal Biosciences. (n.d.-a). The woolly mammoth de-extinction project. https://colossal.com/mammoth/.

Colossal Biosciences. (n.d.-b). Colossal Biosciences: Company. https://colossal.com/company/.

Rafferty, J. P. (2025, December 10). Biodiversity loss: Causes, effects, & facts. In Encyclopædia Britannica. https://www.britannica.com/science/biodiversity-loss

Esvelt, K. M., & Gemmell, N. J. (2017). Conservation demands safe gene drive. PLOS Biology, 15(11), e2003850. https://doi.org/10.1371/journal.pbio.2003850

Hald-Mortensen, C. (2023). The main drivers of biodiversity loss: A brief overview. Journal of Ecology and Natural Resources, 7(3), Article 000346. https://doi.org/10.23880/jenr-16000346

IUCN Species Survival Commission. (2016). IUCN SSC guiding principles on creating proxies of extinct species for conservation benefit (Version 1.0). International Union for Conservation of Nature. https://portals.iucn.org/library/efiles/documents/Rep-2016-009.pdf

Kosch, T. A. (2022, January 17). Using genetics to conserve wildlife. Pursuit. https://pursuit.unimelb.edu.au/articles/using-genetics-to-conserve-wildlife

Paine, R. T. (1969). A note on trophic complexity and community stability [Letter to the editor]. The American Naturalist, 103(929), 91–93. https://www-jstor-org.ezproxy.collegeofsanmateo.edu/stable/pdf/2459472.pdf?refreqid=fastly-default%3Ae12baecbab094efc3bcc20ce96d3bfcc&ab_segments=&initiator=&acceptTC=1

Power, M. E., Tilman, D., Estes, J. A., Menge, B. A., Bond, W. J., Mills, L. S., Daily, G., Castilla, J. C., Lubchenco, J., & Paine, R. T. (1996). Challenges in the quest for keystones. BioScience, 46(8), 609–620. https://www-jstor-org.ezproxy.collegeofsanmateo.edu/stable/pdf/1312990.pdf?refreqid=fastly-default%3A6912d84d69db84aa819c0b9b4f4e6994&ab_segments=&initiator=&acceptTC=1

Svenning, J.-C., Pedersen, P. B. M., Donlan, C. J., Ejrnæs, R., Faurby, S., Galetti, M., Hansen, D. M., Sandel, B., Sandom, C. J., Terborgh, J. W., & Vera, F. W. M. (2016). Science for a wilder Anthropocene: Synthesis and future directions for trophic rewilding research. Proceedings of the National Academy of Sciences, 113(4), 898–906. https://doi.org/10.1073/pnas.1502556112

The Humane Society of the United States. (2006). Welfare issues with genetic engineering and cloning of farm animals. WellBeing International Studies Repository. https://www.wellbeingintlstudiesrepository.org/hsus_reps_impacts_on_animals/21

U.S. Fish and Wildlife Service. (2024, November 1). Advancements for black-footed ferret conservation continue with new offspring from cloned ferret. https://www.fws.gov/press-release/2024-11/advancements-black-footed-ferret-conservation-continue-new-offspring-cloned

Farquhar, B. (2025, March 10). Wolf reintroduction changes ecosystem in Yellowstone. Yellowstone Park. https://www.yellowstonepark.com/things-to-do/wildlife/wolf-reintroduction-changes-ecosystem

National Park Service. (2025, September 9). History of wolf management. https://www.nps.gov/yell/learn/historyculture/wolf-management.htm

Wilmut, I., Schnieke, A. E., McWhir, J., Kind, A. J., & Campbell, K. H. S. (1997). Viable offspring derived from fetal and adult mammalian cells. Nature, 385(6619), 810–813. https://keep.lib.asu.edu/items/172864

Annaratone, L., De Palma, G., Bonizzi, G., Sapino, A., Botti, G., Berrino, E., Mannelli, C., Arcella, P., Di Martino, S., Steffan, A., Daidone, M. G., Canzonieri, V., Parodi, B., Paradiso, A. V., Barberis, M., & Marchiò, C. (2021). Basic principles of biobanking: From biological samples to precision medicine for patients. Virchows Archiv, 479(2), 233–246. https://doi.org/10.1007/s00428-021-03151-0

Almberg, E. S., Cross, P. C., Dobson, A. P., Smith, D. W., & Hudson, P. J. (2012). Parasite invasion following host reintroduction: A case study of Yellowstone's wolves. Philosophical Transactions of the Royal Society B: Biological Sciences, 367(1604), 2840–2851. https://doi.org/10.1098/rstb.2012.0019

Martinelli, S. C. (2024). Cloning of extinct or endangered species. EBSCO Research Starters. https://www.ebsco.com/research-starters/zoology/cloning-

Photo: *Swing Set* by Maria McCambridge

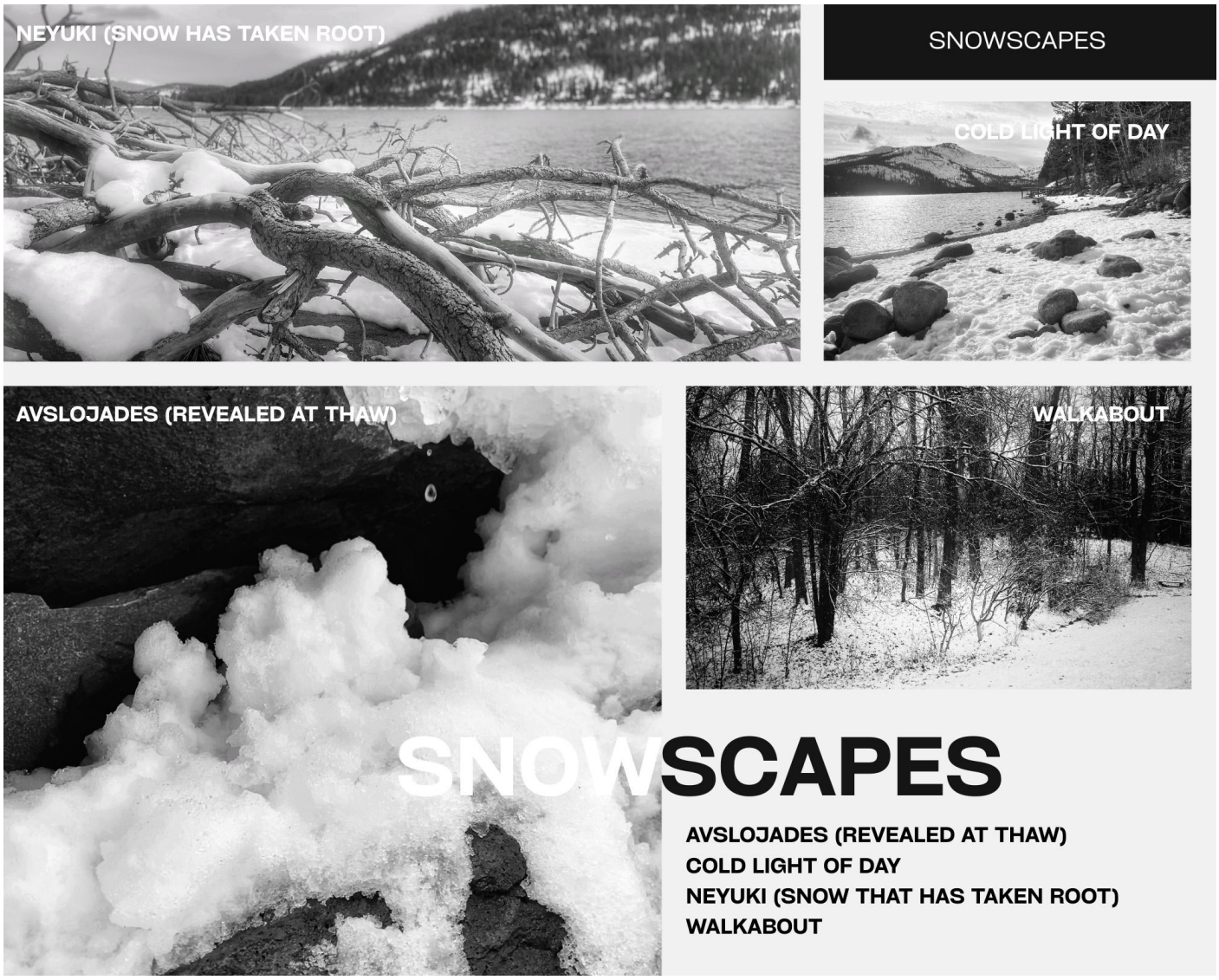


Photo: *Snowscapes* by Phượng Hoàng

Flight Path to Safety

Alan Alcantara

Abstract

Many aviation accidents have occurred because Angle of Attack (AoA) sensors reported incorrect data to a plane's nose dive system. Using MATLAB, I analyzed failure data from malfunctioning AoA sensors involved in real crashes. Through array operations, custom functions, and conditional logic such as if else and switch case statements, I simulated how faulty inputs affect aircraft behavior. These simulations allowed me to design a more reliable dual sensor algorithm and test its performance in a flight simulation environment. The results showed that a dual AoA sensor system is significantly safer than a single sensor system, reducing the likelihood of false nose dive commands.

Introduction

Aviation plays a major role in daily life, whether for travel, business, or life changing opportunities. According to the Federal Aviation Administration, about 3 million passengers fly in and out of the United States each day, and worldwide that number reaches 13.7 million, over 5 billion passengers per year. Although commercial aviation is generally safe, accidents still occur. The International Air Transport Association reports roughly 1.13 accidents per million flights, resulting in more than 1,200 incidents annually in the United States alone.

As an aspiring engineering student, I may not be able to prevent accidents directly, but I can contribute to understanding and reducing their causes. My Honors project focuses on analyzing failure data from Angle of Attack sensors, which play a critical role in determining wing lift based on airflow. AoA related errors have appeared in many cases, but the most well known involve the Boeing 737 MAX 8, an aircraft once marketed as the most fuel efficient single aisle plane of the 2020s.

Through ENGR 215, I gained access to MATLAB, a powerful tool for data analysis, modeling, and simulation. This project uses MATLAB to examine AoA sensor data from documented incidents, simulate sensor behavior under extreme conditions, and propose solutions to reduce or prevent future crashes. It incorporates vectors, conditional control structures such as if else and switch case statements, and custom functions to model system behavior. By integrating case studies, I aim to explore how improved sensor methods might have changed the outcomes of past accidents.

Even saving a single life through better engineering is meaningful. By combining STEM analysis with real aviation data, this project seeks to contribute to safer skies and a safer environment for passengers, while deepening my understanding of how computational tools like MATLAB can support aerospace safety.

Background

An aircraft relies on many components working together, including wings that generate lift, engines that provide thrust, the fuselage that carries passengers, and tail surfaces that provide stability. These parts form a cohesive system, and one of the most important elements within that system is the Angle of Attack sensor. The AoA sensor measures the angle between the wing's chordline and the airflow. As the aircraft moves through the air, the wind strikes the wing at a certain angle, and the sensor detects this information to determine whether the plane should continue climbing or adjust its pitch. It then reports this data to the control system, which decides if the aircraft can keep rising or if it needs to initiate a nose down response (Collins).

While AoA sensors function properly most of the time, failures can have serious consequences. The Boeing 737 MAX 8, which first flew on May 22, 2017, entered service with significant excitement as one of the most fuel efficient single aisle aircraft on the market. With nearly 4,800 orders and widespread use by major airlines, it also introduced a new system called MCAS, designed to automatically adjust the aircraft's pitch based on AoA data. However, after two fatal crashes, concerns grew. On October 29, 2018, the aircraft crashed on a flight from Jakarta to Pankal Pinang, and six months later, on March 10, 2019, another crash occurred on a flight from Ethiopia to Kenya. Both incidents shared two key similarities. MCAS repeatedly forced the aircraft into a nose dive that pilots could not override, and the AoA sensors feeding data to MCAS were faulty because the aircraft relied on only one sensor instead of both (Seyer; Beasley).

This project uses MATLAB and its conditional if else and switch case structures to examine whether using two AoA sensors could have changed the outcomes of these crashes. By focusing on the AoA readings and their relationship to MCAS, MATLAB can calculate discrepancies between sensors and determine whether the data is reliable. Even under extreme conditions such as turbulence, wind shear, stall risk, or repeated AoA readings, the simulations show how a dual sensor approach could identify faulty inputs and prevent the types of failures that contributed to these accidents.

Body

Before presenting the results, it is important to explain how the experiment was conducted. MATLAB has several key features that make the simulation possible. First, MATLAB can store variables using the equal sign, allowing any letter or combination of letters to represent a number, value, or message.Second, MATLAB uses functions, which act like black boxes. The user inputs data, and the function processes that information to produce one or more outputs. Third, MATLAB allows conditional statements such as if else, which check whether certain conditions are true and display the corresponding output. If none of the conditions are met, the program defaults to an else statement. MATLAB also uses switch case structures, where a switch identifies the input being evaluated and each case represents a possible input option. Whichever case matches the input determines the output.

With these features in place, this project calculates the discrepancy between two AoA sensors and inputs that information into a simulation to determine whether a plane would avoid a crash. The user can enter any pair of AoA values, and MATLAB computes the difference between them. That discrepancy is then evaluated through the if else statements to produce an output. Below is an example of the code used for the normal flight condition:

```
function [safeAoA, statusMessage] = AoA_Normal(sensor1, sensor2)
discrepancy = abs(sensor1-sensor2);
if discrepancy <= 10
   safeAoA = mean([sensor1,sensor2]);
   statusMessage = 'Normal operation.';
elseif discrepancy <= 15
   safeAoA = mean([sensor1,sensor2])+2;
   statusMessage = 'Moderate discrepancy detected. AoA adjusted slightly.';
else
   safeAoA = mean([sensor1,sensor2]) + 5;
   statusMessage = 'Critical discrepancy detected! Manual Pilot control required.';
end
end
```

The function takes two inputs, sensor1 and sensor2, which are chosen by the user before the simulation begins. Under normal conditions, the discrepancy is the absolute difference between the two readings. If this difference is less than or equal to 10, the safeAoA is calculated as the average of the two values and the statusMessage displays Normal Operation. If the discrepancy does not meet the earlier conditions, MATLAB continues evaluating until it finds a matching statement. When the discrepancy exceeds 15, the code triggers a critical warning, indicating that manual pilot control is required and that autopilot should be canceled.

I created eleven functions in total, each designed to simulate different circumstances and compare the performance of one AoA sensor versus two. Five functions were built for dual sensor inputs, five for single sensor inputs, and a master function was created to call each condition and return the output. The five simulated conditions were normal flight, wind shear, stall, repeated AoA readings, and turbulence.

The MATLAB simulations demonstrate a clear difference in success rates between using one sensor and using two. By inputting real AoA data from failed flights, the simulation provides an opportunity to test actual Boeing readings. In the Lion Air Final Accident Report, the left AoA sensor incorrectly showed 20.7 degrees on takeoff while the right sensor showed negative 1.3 degrees. Since the chordline should not be struck at such a steep angle during takeoff, the right sensor was correct. However, the aircraft used the faulty left sensor, which fed incorrect data to MCAS and caused it to activate 21 times during the 11 minute flight, ultimately forcing the plane into repeated nose dives that pilots could not override (National). Six months later, the Boeing 737 MAX 8 experienced another crash when the left AoA sensor reported 74.5 degrees while the right showed only 15.3. Again, the aircraft relied on the faulty sensor, MCAS activated, and the pilots were denied manual control (Ethiopian).

Using this data and other failed flight readings, the MATLAB simulation determines whether a nose dive command would be triggered and whether the system can detect a faulty sensor. With the if else and switch case logic built into the functions, the crash data was analyzed across all conditions. The trend is clear. Using two AoA sensors produces significantly safer outcomes. Ten identical data pairs were tested in each function, and MATLAB produced outputs showing the safe AoA and the plane's corresponding action. To avoid overwhelming the reader, I chose to highlight the most important condition, which was normal flight. The tables one the folloing page show the angle inputs, the calculate safe AoA, and the resulting decision.

Analysis

The most important information shown in the tables is the safe AoA value and the message sent to MCAS. For example, the 10 and 12 AoA inputs produced nearly identical results in both systems. However, pairs like 20 and 25 show a clear difference. With dual sensors, the safe AoA is 22.5 and the plane remains in normal operation. In the single sensor system, the safe AoA defaults to sensor1, and the system initiates a nose dive command based solely on that one value. This mirrors what happened in the Boeing crashes.

Testing real data is even more revealing. In the Lion Air crash, the single sensor system used the incorrect 20.7 degree reading and initiated a nose dive immediately after takeoff (National). The dual sensor simulation averaged the values to 14.35 and required manual pilot mode instead of an automatic nose dive. The same pattern appears with the Ethiopian Airlines data. The single sensor reported 74.5 degrees, causing MCAS to activate, while the dual sensor system averaged the readings to 49.9 and required manual pilot control (Ethiopian).

Across every condition tested, the dual sensor system consistently outperformed the single sensor system. Every simulation using dual sensors prompted a manual override when needed, while the single sensor system repeatedly initiated nose dive commands. This demonstrates how redundancy can reduce accidents and fatalities.

Given this data, it is crucial for aircraft manufacturers to integrate dual AoA sensors. A dual sensor system can feed more reliable information into control systems like MCAS and autopilot, improving decision making and reducing the risk of relying on a single faulty input. This is especially important during takeoff and landing. Modern AoA systems are already being designed to use two sensors even under extreme conditions such as wind shear and turbulence (Collins). The FAA has also emphasized the importance of updating and maintaining AoA sensor performance (Federal). These developments show that improved AoA implementation is essential for safer commercial aviation.

MCAS and similar systems have faced intense scrutiny because of their reliance on a single AoA sensor. FAA investigations into the Boeing 737 MAX 8 found that MCAS was coded to use only one AoA input, which caused multiple nose dive activations shortly after takeoff (Federal Aviation: "Summary"). If Boeing had used both sensors and implemented a discrepancy threshold similar to the logic in this MATLAB project, MCAS could have been disabled when readings disagreed, allowing pilots to retain control. Conditional statements like if else and switch case can be used to code this logic into real aircraft systems. Autopilot systems would also benefit from dual sensors by analyzing both readings and using their average to determine a safe AoA. Implementing this approach would significantly improve aviation safety.

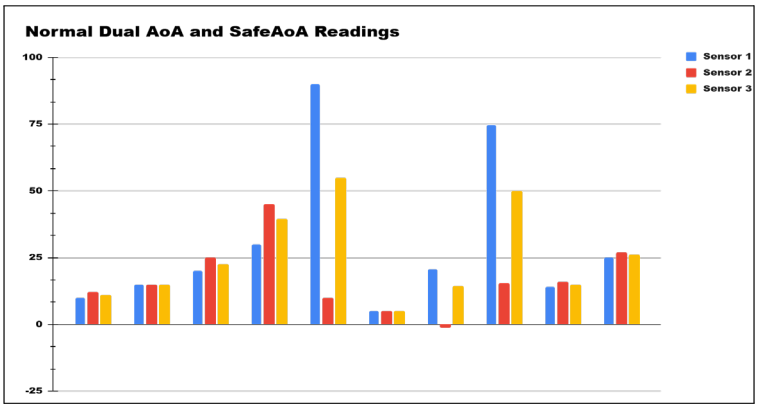
Discussion

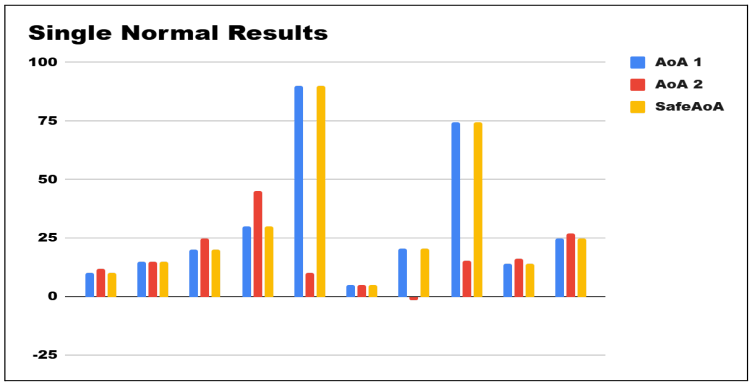
Through many MATLAB trials, the results were clear. Dual sensors consistently performed far better than a single sensor in every situation tested. Unlike the single sensor system, which automatically initiated a nose dive response based on only one reading, the dual sensor system produced more accurate outputs by detecting discrepancies between the two inputs. In conditions such as normal flight, turbulence, wind shear, stall risk, and repeated AoA readings, the dual sensors communicated with each other, averaged their values, and calculated a safer AoA. This allowed MCAS to determine when manual autopilot was needed or when the aircraft could continue climbing. The single sensor system, unable to compare readings, could not detect faulty data and therefore produced unsafe commands.

The most significant evidence came from testing the exact AoA data recorded during the two Boeing 737 MAX 8 crashes. In both accidents, the aircraft relied on only one AoA sensor, which produced extreme discrepancies such as 74.5 and 15.3 degrees. The single sensor system accepted the faulty value, leading to repeated MCAS activations and ultimately a crash (Dingemans). MATLAB reproduced this outcome. However, when the same data was entered into the dual sensor simulation, the system averaged the readings and produced a non crash output. This contrast highlights the critical difference between the two approaches.

Despite the clear advantages of dual sensors, some argue that programming aircraft to use both sensors is challenging. Implementing conditional logic such as if else and switch case statements requires advanced coding and significant development time. The NRC notes that many failures in the 737 MAX 8 stemmed from software issues, demonstrating how difficult it can be to optimize AoA sensor functions (U.S.). Another concern is sensor disagreement. If two sensors differ greatly, which one should the aircraft trust? Without a clear threshold or logic, conflicting inputs could confuse MCAS and cause it to rely on a single sensor. This has led some experts to recommend using three AoA sensors instead of two. However, if coding one sensor is already difficult, coding three becomes even more complex. There are also cost and maintenance concerns, since adding

# AoA 1	# AoA 2	# SafeAoA	Message
10	12	11	Normal Operation
15	15	15	Normal Operation
20	25	22.5	Normal Operation
30	45	39.5	Moderate Discrepancy Detected. AoA adjusted slightly
90	10	55	Critical Discrepancy Detected! Manual Pilot control required
5	5	5	Normal Operation
20.7	-1.3	14.35	Critical Discrepancy Detected! Manual Pilot control required
74.5	15.3	49.9	Critical Discrepancy Detected! Manual Pilot control required
14	16	15	Normal Operation
25	27	26	Normal Operation





# AoA 1	# AoA 2	# SafeAoA	Message
10	12	10	Normal AoA based on 1 sensor.
15	15	15	Normal AoA based on 1 sensor.
20	25	20	High AoA detected. Reporting to MCAS, initiating nose dive!
30	45	30	High AoA detected. Reporting to MCAS, initiating nose dive!
90	10	90	High AoA detected. Reporting to MCAS, initiating nose dive!
5	5	5	Normal AoA based on 1 sensor.
20.7	-1.3	20.7	High AoA detected. Reporting to MCAS, initiating nose dive!
74.5	15.3	74.5	High AoA detected. Reporting to MCAS, initiating nose dive!
14	16	14	Normal AoA based on 1 sensor.
25	27	25	High AoA detected. Reporting to MCAS, initiating nose dive!

more sensors increases manufacturing expenses and the potential for damage. AoA sensors are delicate, and without proper installation they can be easily harmed (Federal).

Even so, these concerns do not outweigh the potential to prevent crashes and save lives. If AoA sensors produce drastically different readings, the system should never initiate an automatic nose dive that removes pilot control. The logic used in this project, calculating a discrepancy and averaging the sensors, offers a safer alternative. Aircraft can be programmed with a threshold beyond which MCAS must defer to manual control. Manual override is far safer than an automatic nose dive command because it gives trained pilots the opportunity to correct the situation. As for programming difficulty, the additional effort is justified. With more than 1,200 aviation accidents occurring annually in the United States, improved coding could save hundreds or even thousands of lives. Financially, the cost of adding a second or third sensor is far lower than the cost of a major crash. A single aviation disaster, such as those involving the Boeing 737 MAX 8, can cost between 11.6 and 120 million dollars (Li). This amount is incomparable to the cost of installing and coding a dual sensor system. Regular maintenance and proper installation should also be standard practice, as preserving AoA sensors directly contributes to safer flight operations. The FAA has already mandated that the Boeing 737 MAX 8 and other aircraft be equipped with three AoA sensors (Aeropeep), reinforcing the importance of redundancy in modern aviation.

Conclusion

This project highlights the computational methods essential to engineering, particularly within the aviation industry. By using MATLAB to simulate crashes caused by AoA discrepancies, it becomes clear that investing more care, time, and effort into a dual sensor system is far more effective than relying on a single sensor. Ensuring safe and reliable air travel should remain a priority for every aviation company, and analyzing past crash data through comprehensive simulations is crucial for strengthening confidence in aircraft systems. The additional attention required to implement dual or even triple AoA sensors is justified, as failing to do so places passenger safety at risk.

Works CIted

Aeropeep. (2023, March 15). Should Boeing 737 MAX be refitted with three angle of attack (AOA) sensors given the risk uncovered from recent accidents? Aeropeep. aeropeep.com/should-boeing-737-max-be-refitted-with-three-angle-of-attack-aoa-sensors-given-the-risk-uncovered-from-recent-accidents/.

Beasley Allen Law Firm. (2019, April 30). Boeing 737 Max 8: Sacrificing safety to the bottom line? Beasley Allen. www.beasleyallen.com/article/boeing-737-max-8-plane-crashes-reveal-major-safety-flaws/.

Collins Aerospace. (2017). Angle of attack (AOA) systems. UTC Aerospace Systems. www.collinsaerospace.com/-/media/CA/product-assets/files/commercial/flight-deck/surveillance/air-data-systems/angle-of-attack-aoa-systems.pdf?rev=5334a65820844e7ebc8b8b89d7bf4422.

Dingemans, Jop. (2025, February 9). What went wrong with the Boeing 737 MAX: The WHY Spotlight #4. Pilots Who Ask Why. pilotswhoaskwhy.com/2025/02/09/what-went-wrong-with-the-boeing-737-max-the-why-spotlight-4/.

Ethiopian Civil Aviation Authority. (2019). Preliminary accident investigation report: Ethiopian Airlines flight ET302, Boeing 737-8 (MAX), ET-AVJ. Addis Ababa, Ethiopia: Ethiopian Civil Aviation Authority. www.ethiopianairlines.com/error?aspxerrorpath=/docs/default-source/default-document-library/preliminary-report-et302.pdf.

Federal Aviation Administration. (2019). InFO 19009: Boeing 737-8/-9 flight control system, angle of attack (AOA) disagree alert and MCAS. Washington, DC: U.S. Department of Transportation. www.faa.gov/sites/faa.gov/files/other_visit/aviation_industry/airline_operators/airline_safety/InFO19009.pdf.

Federal Aviation Administration. (2020). Summary of the Boeing 737 MAX return to service decision. Washington, DC: U.S. Department of Transportation. www.faa.gov/sites/faa.gov/files/2022-08/737_RTS_Summary.pdf.

Li, G., Baker, S. P., Grabowski, J. G., & Rebok, G. W. (2003). The cost of general aviation accidents in the United States. Accident Analysis & Prevention, 35(6), 779–785. www.researchgate.net/publication/257424734_The_cost_of_general_aviation_accidents_in_the_United_States.

National Transportation Safety Committee (KNKT). (2019). Final aircraft accident investigation report: Lion Air flight JT610, Boeing 737-8 (MAX), PK-LQP. Jakarta, Indonesia: KNKT. knkt.dephub.go.id/knkt/ntsc_aviation/baru/Final%20Report%20PK-LQP.pdf.

Seyer, Katherine. & Londer, Edward. (2020). Case Study of the Boeing 737 MAX 8 Crashes Using a Systems Thinking Approach. Department of Systems **Engineering United States Military Academy, West Point, NY. ieworldconference.org/content/WP2020/Papers/GDRKMCC_20_30.pdf.**

U.S. Nuclear Regulatory Commission. (2022). BOEING 737 CRASHES:

Photo: *Still Life 3* by Maria-Gracia Inglessis

From Plants to Big Mac™: Unlocking Meat-Like Flavor & Texture

Meylin Zoe Law Cotrina

Abstract

The purpose of this research is to investigate the chemical processes that allow plant-based meats to simulate the taste and texture of traditional meat. This paper examines the key reactions that enhance the sensory properties of plant-based meats. The development of plant-based burgers relies on advanced chemical processes, principally the Maillard reaction involving food-derived peptides, generating meat-like flavor compounds, and the high-moisture extrusion for the fibrous texture of traditional meat. In addition, extracted and fermented leghemoglobin significantly increases meat-like volatile compounds when they are grilled, notably boosting pyrazine formation. Plant protein sources allow scientists to customize flavors based on specific quantities, similar to meat structure, for a broader range of meat analogs.

Introduction

If meat as we know it suddenly disappeared, would you eat a plant-based burger that tastes, looks, and feels just like real meat? Seven million years ago, Homo sapiens consumed meat, and to this date we still do. Meat has always been a staple on most people's diets, but how does meat production impact the environment compared to plant-based alternatives? If the traditional meat production and management mode remains unchanged, an increase of 30–50% of the land for animal husbandry and meat production will be needed to meet the excessive demand (Sun, et al). As a result, the excessive production of meat has led to environmental damage, according to Dopelt, Keren, "It is estimated that 18% of global greenhouse gas emissions are caused by the livestock industry. The amount of carbon dioxide (CO2) released to the atmosphere is estimated at approximately 7516 million tons per year" (Dopelt, et al.).

The situation has driven the development of meat alternatives that work to compete with the large meat market. Since most consumers are not committed to vegetarian or vegan diets, and the food industry with plant-based meats simulates the sensorial, nutritional value, and even appearance of real meat to stay noticeable. It is of the utmost importance for food companies to reinvent themselves to simulate the texture and flavor of meat with plant-based ingredients and chemical methods. Regardless of the advances in food technology, most consumers are not attracted to the idea of meat or burgers made from plants, which challenges food scientists to develop alternatives that closely replicate the real thing. As a result, the following research paper analyzes the composition of plant-based meats, specifically burgers, and the applied procedures to understand how they meet consumer expectations.

Composition of Plant-Based Burgers

An in-depth comparative analysis of plant-based burgers (PBB) and meat-based burgers (MBB) highlights significant differences in composition, pH levels, amino acid profiles, lipid content, and mineral concentrations, which collectively impact their structural characteristics and nutritional value. To begin their comparison, we will be analyzing the composition of one of the most popular PBB brands, Impossible Foods™, with a common MBB. The ingredients listed in the Impossible™ Burger are Water, Soy Protein Concentrate, Sunflower Oil, Coconut Oil, 2% Or Less Of: Natural Flavors, Methylcellulose, Cultured Dextrose, Food Starch Modified, Yeast Extract, Dextrose, Soy Leghemoglobin, Salt, Vitamin E (Tocopherols), L-Tryptophan, and Soy Protein Isolate.

Physical and Chemical Properties

Starting with the physical and chemical properties of both raw patties, the PBB analyzed had a slightly higher and changeable pH than the raw MBB. The median pH for PBB was 5.81 (95% CI50%: 5.58–7.29) compared to 5.48 for MBB (95% CI50%: 5.28–5.70) (Table 1) (2). The raw burger patties' pH level was measured using a Crison Basic 20 pH meter. The final value for each sample was the average of five reads. Two burgers from each traditional meat brand (n = 8) and three burgers from the PBB brand (n = 9) were analyzed (De Marchi, M. et al). The pH has a crucial role in pigments responsible for the color of fruits, vegetables, and meat.

The color components of each raw burger were assessed at room temperature (18.6 °C to 19.5 °C) with a Minolta CM-600d colorimeter, device used to measure the amount of color involved in a chemical, using the specular component included mode with 10° standard observer, D65 illuminant and an aperture of 8 mm, according to CIE-lab30. The color of food impacts the quality trait as it is involved in the sensory perception and consumers' acceptance. Due to the variety of ingredients and a greater level of alkalinity of the raw PBB, it has a slightly higher pH compared to MBB. However, as they stay at a similar pH level, the PBB successfully replicates the color of the real meat. The major differences in Table 1 are the a* and b* components because of the content level of hemoglobin, heme prosthetic group, as PBB lacks erythrocytes and myoglobin. Regardless of their lack of red blood cells, PBB contains legumes such as soy that have an amount of symbiotic hemoglobin called leghemoglobin, the soy protein, and soy leghemoglobin as ingredients, creating the impression of "bleeding" to better imitate meat.

Nutritional Profile

Carbohydrates and Fiber:

The differences in carbohydrates and dietary fiber content between the two result in PBB being in higher levels than MBB. Plant-based meats commonly have higher carbohydrate content compared to traditional meat due to ingredients like grains, legumes, and other plant-derived components that naturally contain carbohydrates. Soy is a valuable ingredient not only for its nutritional content, with soy seeds and flours being rich in protein, unsaturated fat, soluble and insoluble fiber, and micronutrients such as B vitamins or vitamin E (Costa-Catala, et al). Therefore, PBB from its ingredients, more precisely soy, provides fiber, while MBB does not. For example, Impossible™ Burger typically contains around 5 grams of dietary fiber per patty, 113 grams.

Protein:

There is no significant difference between their protein content. The median protein of disulfide bonds the content was 18.01% of the raw product for PBB and 17.96% for MBB (S-Table 1, 2). The Impossible™ Burger can simulate MBB protein content by using soy protein isolate, which is a concentrated form of protein extracted from soybeans. Despite similar total protein content, the detailed amino acid profiles showed significant differences in five out of the eighteen identified amino acids (S-Table 4, 2). Hydroxyproline, a key component of collagen, was only identified in MBB samples. Alanine, glycine, and methionine were less abundant in PBB than in MBB. The lower methionine content in PBB is consistent with the fact that soy protein isolates are generally low in methionine compared to animal-based proteins. However, the use of plant-based protein blends helps to reduce differences in amino acid profiles of real meat, using as an example other brand of PBB, Beyond Meat®, their burgers contain pea

Trait[2]	Meat-based burger		Plant-based burger		
	Median	95% $CI_{50\%}$	Median	95% $CI_{50\%}$	*p*
pH	5.48	5.28–5.70	5.81	5.58–7.29	0.038
L*	44.89	42.36–48.61	47.99	39.87–48.90	0.481
a*	19.82	16.95–20.94	16.83	15.60–17.45	0.032
b*	14.46	13.57–15.88	11.21	9.63–11.77	0.004

Table 1. Analysis of pH and color (median and 95% $CI_{50\%}$[1]) of raw burgers. [1]95% $CI_{50\%}$: median 95% confidence interval. [2]Color components: L*, lightness; a*, green–red; b*, blue-yellow.

protein, which is rich in lysine, with rice protein, higher in methionine, and other ingredients to create a complementary protein profile nearer to meat. Besides, cysteine and glutamic acid are more abundant in PBB than in MBB, because they are naturally contained in certain plant proteins. Cysteine acid enables the formation of disulfide bonds, which are critical for protein structure and texture. This property is particularly relevant in plant-based meat formulations, as cysteine contributes to their fibrous texture and structure. This is supported by the study of Gao, Yang, which investigated the role of cysteine in fibrous structure formation during high-moisture extrusion of plant proteins (Gao, et Al).

Fatty Acids:

PBB had no significant difference from MBB in total fats. The median total fat content for PBBs was 11.10% of the raw product, while MBBs had 12.51% (S-Table 1, 2). Fatty acids are carboxylic acids with a long aliphatic tail called a chain, which are either saturated or unsaturated. These acids are divided into four categories: saturated, monounsaturated, polyunsaturated, and trans fats. Following the analysis of saturated (SFAs), monounsaturated (MUFAs), polyunsaturated (PUFAs), and trans fats (trans-FAs) by De Marchi, M., Costa, A., Pozza, M. in their research paper Detailed characterization of plant-based burgers, the investigation was conducted by identifying and quantifying individual fatty acids, rather than measuring fat categories directly. First, total lipids were extracted from raw burger samples using petroleum ether via the AOAC International method #960.39, which involves drying the sample, placing it in a thimble, and extracting it with petroleum ether. These lipids were then converted into fatty acid methyl esters (FAMEs) through a methylation process involving sulfuric acid in methanol and heating. The resulting FAMEs were separated and analyzed using gas chromatography with a flame ionization detector. Therefore, individual fatty acids were identified by comparing their retention times with a standard mix, and their quantities were expressed as percentages of total fatty acids. As shown in Table 2 Fatty Acids, the grouped fat types (MUFA, PUFA, trans-FA) of PBB demonstrated being lower than MBB, except the saturated fats, which were 3.4% higher than MBB, due to the use of coconut oil as a major ingredient. Finally, PBB exhibited a significantly lower cholesterol content compared to MBB.

Mineral Composition:

Plant-based burgers are generally richer in minerals compared to meat-based burgers. To measure the total mineral content of both, the study by De Marchi, M., Costa, A., Pozza, M had to determine the ash content of both raw burgers. The researchers in the study used a specific method described in the General composition of the raw product section. "The total Ash was measured gravimetrically by igniting samples in a muffle furnace at 550 °C for 4 h" (De Marchi, M. et al). This is following the Association of Official Analytical Chemists (AOAC) method #920.153. In simpler terms, they weighed both patties, placed them in a muffle furnace, which is a type of high-temperature oven, and heated them to 550°C for 4 hours. This high temperature incinerates the organic components of the burger. After this process, only the inorganic mineral components remain as ash, which is weighed gravimetrically, meaning its weight was measured. The study found that the median Ash content in PBB was 0.73% higher compared to MBB. Zinc (Zn) was less abundant in PBB compared to MBB. Iron (Fe) content was twice as high in PBB (26.51 mg/kg) as in MBB (13.05 mg/kg). PBB showed higher magnesium content (Mg) with 614.94 mg/kg, while MBB had 159.42 mg/kg, and had Lithium content due to the main dietary sources of lithium being cereals and vegetables (S-Table 3, 2).

Mimicking Flavor

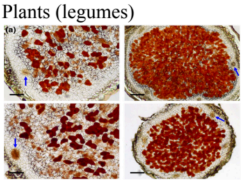
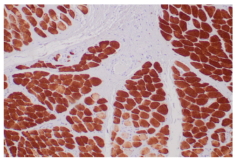
Plant-based meat companies for consumer acceptance have replicated the flavor of meat through the use of the "myoglobin" from legumes called leghemoglobin, its genetic modification to produce enough heme for PBBs production, and the chemical process, the Maillard Reaction, that finally produces the browning effect, aroma and flavour of cooked burgers.

Heme Protein From Plants:

According to Pat Brown, CEO of Impossible Foods™, and his research team, many meat-specific aromas rely on heme interactions with cellular proteins and biomolecules as it cooks. " 'Heme catalyzes very specific types of chemical reactions, ' said Brown, 'that transform abundant, simple nutrients into this explosion of hundreds of diverse volatile odorant molecules. When you experience them, together they add up unmistakably to the smell and taste of meat' " (Wolf). Leghemoglobin is a type of heme protein found in legumes, specifically in the root nodules. Its primary role is to regulate oxygen levels within the nodules by binding to oxygen. This maintains a low enough concentration for nitrogen-fixing bacteria (rhizobia) to function efficiently, while still supplying enough oxygen for the bacteria's respiration. The presence of this type of heme is what gives legume root nodules their bright pink color.

Leghemoglobin (PBB) vs. Myoglobin (MBB):

Leghemoglobin is a heme protein that has a symbiotic relationship with nitrogen-fixing bacteria. On the other hand, Myoglobin is a heme protein in muscles that is in charge of oxygen transportation, involved with electron transport, and redox reactions. Leghemoglobin and Myoglobin are similar heme proteins but operate in different ways. They both bind oxygen using their iron-containing molecule, both regulate oxygen availability in their respective structures, and both contribute to the red or pink color of their tissues: myoglobin in muscle and leghemoglobin in root nodules.

Feature	Leghemoglobin	Myoglobin
Found in	Legume root nodules	Animal muscle tissue
Function	Regulates oxygen to support nitrogen fixation by rhizobia	Stores oxygen for muscle metabolism
Organism	Plants (legumes) 	Animals 
Source in food science	Used in plant-based meat for flavor & color	Naturally in real meat, responsible for meat's red color

Leghemoglobin from Yeast:

Large quantities of soy leghemoglobin can be produced using Pichia Pastoris (yeast). The process to separate nodules from roots and soil, and purify the leghemoglobin, was too demanding and inefficient for industrial production, as a result, Impossible Foods™ turned to recombinant protein production using yeast. Through the recombinant system, they were allowed to explore different heme sources, soy leghemoglobin ultimately proved to be the best fit for creating the desired meat flavor profile. Pichia pastoris is a yeast used for large-scale production of various recombinant proteins, including those for therapeutics and food preparation. It was specifically chosen for its capacity to house complex metabolic pathways involved in heme protein production. For this reason, their scientific team used a special version of the yeast, MXY0291, which was made by starting with a safe strain (NRRL Y-11430), a genetically modified microorganism (yeast) that is nontoxigenic and nonpathogenic.

According to Fraser et al., "MXY0291 was modified to overexpress the gene encoding the soy LegH as well as all 8 enzymes in the native Pichia heme biosynthesis pathway using the Pichia alcohol oxidase 1 promoter (pAOX1). MXY0291 was also modified to overexpress the Mxr1 transcriptional activator using the pAOX1 promoter. The Mxr1 protein activates the pAOX1 promoter, leading to increased expression of pAOX1-driven LegH, heme biosynthesis genes, and Mxr1 itself" (Fraser, et al). So, the modified MXY0291 has two key functions: to produce soy LegH protein, and to enhance the yeast's natural ability to make heme by overexpressing all 8 enzymes in Pichia's native heme production pathway. These enzymes help the yeast create heme from basic building blocks. In addition, MXY0291 was modified to overexpress the Mxr1 transcriptional activator, which helps to drive the expression of genes required for LegH and heme production using the pAOX1. The food engineers from Impossible Foods™ have rebuilt and enhanced the yeast's entire heme-making system, which ensures the yeast can produce not just LegH protein, but also enough functional heme groups to go with it. The use of the pAOX1 promoter and Mxr1 has allowed the scalable production of LegH that tastes like real meat.

Maillard Reaction:

Through chain stages of sugar dehydration, fragmentation, and amino acid degradation, the Maillard Reaction can be precisely manipulated to produce desirable meaty flavors from soybeans. The Maillard reaction is a non-enzymatic chemical process between amino acids and reducing sugars when heated, that results in a browning effect, complex flavors, and aromas. The MR can be divided into three main stages:

1. Initial Stage: Formation of N-substituted Glycosylamines through a condensation reaction between reducing sugars and amino groups. The Glycosylamine rearranges into more stable structures, the Amadori compound or the Heyns compound.

2. Intermediate Stage: The compounds break down by complex reaction:
a) Sugar Dehydration: Sugar undergoes a loss of water molecules, forming highly reactive compounds like 3-deoxyglucosone and furfural derivatives. Amadori product either loses three molecules of H_2O, forming Furfurals, or loses two to form Reductones.
b) Sugar Fragmentation: The breakdown of sugar molecules through heat and chemical reactions, which splits into compounds like glyoxal, methylglyoxal, and other short-chain aldehydes and ketones.
c) Amino Acid Degradation: Amino acids react with dicarbonyl compounds to produce aldehydes, CO_2, and ammonia. This produces flavor-active aldehydes that contribute to savory, nutty, or roasted flavor profiles.

3. Final Stage: Aldehydes react with amines to form a variety of intermediate compounds, leading to the formation of melanoidins and other advanced Maillard products, which can themselves react to produce further products.

Melanoidins are long, polymeric compounds that act as brown pigments, giving the cooked food its brown colouration. The Maillard reaction is referred to as a non-enzymatic browning reaction because these melanoidins are produced without the aid of enzymes.

The Maillard Reaction is influenced by several factors, including the ratios and types of sugars and proteins involved, the reaction temperature, pH levels, and heating duration. As a result, different reducing sugars can produce distinct flavor profiles when reacting with specific amino acids. Some examples of reducing sugars and their flavor tones: Diacetyl – buttery, Furan – nutty, and Acetaldehyde – rum or cherry component.

Apart from that, the sources of proteins or peptides play a crucial role in determining the resulting flavor of Maillard Reaction Products (MRPs). The manipulation of these factors allows the production of flavor-enhancing compounds modified into specific sensory features. Following the research of Liu, Shuyun, et al. on the insights of flavor and factors influencing the Maillard Reaction, "Soybean peptides have been used to generate a range of flavors, including umami, sweet, salty, and meaty, as a potential flavor precursor. MRPs were made utilizing a xylose and soybean peptide

method after heating at 100–140°C and pH 7.6 for 2 h. MRPs with cysteine addition presented the minimal bitterness, after heating at 140°C, and the highest umami and saltiness at 100°C" (Liu, et al). The study shows that Maillard reaction products produced using xylose and soybean peptides can generate the desired flavor attributes. Meat flavor is characterized by volatile sulfur compounds that contribute sulfur and meat aromas. These compounds can form from the thermal degradation of cysteine and carbonyl compounds or from the reaction of furfural and hydrogen sulfide.

Therefore, there is a strong link between meat proteins and MRP flavors. The potential exists to create a meat-like flavor from plant sources, such as soybeans, by using appropriate precursors, such as peptides and sugars, and by adding sulfur-containing amino acids or other compounds. Specific amino acids, proteins, and peptides affect the formation of characteristic flavor substances in MRPs. First, peptides within the molecular weight range of 128–1,000 Da are primarily responsible for the meat-like flavor. Second, reaction conditions such as temperature and pH impact the types and contents of flavor compounds. As it is demonstrated, high temperatures, like between 100-140°C, can facilitate the formation of volatile compounds like pyrazine, furan, and pyridine, which contribute to barbecue and meat flavor. Therefore, by controlling the reaction conditions, peptide molecular weight, and adding specific sulfur-containing compounds, it is possible to generate meaty flavors from soybeans.

Mimicking Texture

Achieving a meat-like texture in plant-based burgers relies on forming a fibrous structure, often through techniques like high-moisture extrusion. Additives, specifically L-cysteine, can help modify protein structures and enhance fibrousness and texture.

Protein Crosslinking:

The protein crosslinking through disulfide bonds is a dominant contributor to the formation of fibrous structures in plant-based burgers that feel like muscle fibers of real meat. Disulfide bonds are essential covalent bonds that maintain protein molecular cross-linking. In an easier way to see it, these bonds act like chemical links that connect different protein molecules from the same protein molecule, and finally form a network structure. Covalent bonds are the sharing of an electron between two nonmetal atoms. According to Jiang, Lianzhou, et al., increasing disulfide bonds enhances the fiber structure of plant-based meats. The study proves this idea through the experimental ratio change of soy protein isolate (SPI) and wheat gluten (WG). Different samples of both were tried, and their results demonstrated that the addition of WG significantly reduces the hardness and chewiness of PBMs but significantly improves the springiness and brightness of PBMAs. When the ratio of SPI to WG is 9:3, PBMs have the best fiber structure, as there are greater disulfide bonds (Jiang et al.).

L-cysteine:

The addition of L-cysteine to plant-based burgers is a key process to modify protein structure and enhance product quality. L-cysteine is an amino acid that contains reductive sulfhydryl groups. These groups can be oxidized to create cystine through strong disulfide bonds. L-cysteine contains a thiol group (-SH) that participates in sulfhydryl (SH)/disulfide (SS) exchange reactions. When exposed to high-temperature, high-shear processes such as high-moisture extrusion, the reaction stimulates the formation of disulfide bonds between protein molecules. L-cysteine is used as a fibrousness enhancer in moderate samples. Chao's study proves it, "After cooking, the cys-0.4% sample showed a pronounced fibrousness in agreement with its microstructure image. This meat analog displayed a muscle-meat-like structure, improved texture, and reduced beany odor and bitter taste. Excessive cysteine contents (0.5%–0.6%) negatively affected the functionality of meat analogs" (Chao, et al). This research guides the optimal amount of L-cysteine in meat analogs to improve product quality and the resemblance to real meat. Disproportional quantities of L-cysteine can disrupt the protein structure by overexposing reactive groups, which produces a loss of its fibrous property and breaks multiple weak protein linkages.

High-Moisture Extrusion

A method used for industrial production of meat alternatives, which converts plant-based protein isolates into fibrous structures. The study by Schmid, Eva-Maria, High moisture extrusion cooking of meat analogs: A review of mechanisms of protein texturization, details the conditions and process of High-Moisture Extrusion (HME). (Schmid, et al).

Conditions:

HME goes under intense conditions of high temperature, pressure, and shear. It involves a high moisture content, typically above 40%, often ranging from 40% to 70% (w/w) water. The presence of polysaccharides, complex carbohydrates, is key in HME since they act as structuring agents during extrusion. When heated, they help form a dispersed phase, crucial for preventing transversal protein aggregation and maintaining individual protein layers.

Extruder Processing Zones:
Feeding Zone: Proteins are added and mixed with water under mild conditions. This allows hydration without altering protein structure.
Mixing Zone: Temperature and pressure begin to rise, causing minimal bond disruption. L-cysteine is added, promoting protein depolymerization and unfolding.
Melting Zone: High heat and shear lead to protein denaturation, unfolding, and aggregation. Disulfide bonds break and then reform, especially at >90°C and >50% moisture, contributing to fibrous structure formation.
Cooling Zone: The critical step for texturization. Cooling stabilizes bonds and promotes the separation stage under low shear, forming the final fibrous, meat-like structure.

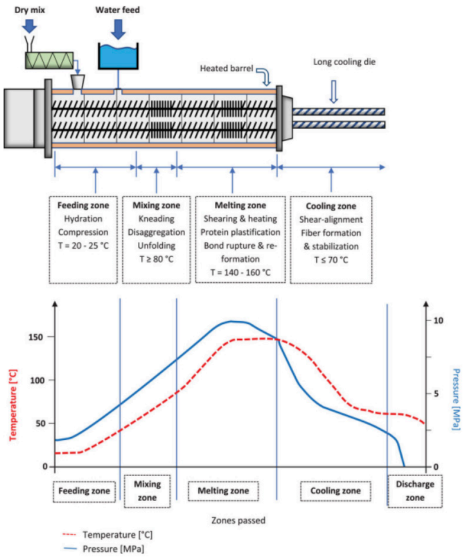


Figure 1. Schematic illustration of the processing zones in an extruder along with the temperature and pressure profiles therein (Schmid, et al).

During HME, proteins undergo major transformations: denaturation, unfolding, degradation, and aggregation, resulting in new fibrous structures. Key interactions include disulfide, hydrogen, and hydrophobic bonding, with disulfide bonds playing a central role in forming the fibrous texture, especially at high moisture levels. High temperature and shear in the melting zone break molecular bonds, while the cooling zone allows these bonds to reform and stabilize the final structure. Fibrous structure formation is driven by protein aggregation and phase separation, the blend of biopolymers, proteins, and polysaccharides, which separate into distinct phases rather than forming a homogeneous mixture. The presence of both dispersed and continuous phases helps prevent unwanted cross-linking across layers, allowing the development of distinct, layered, meat-like fibers.

Conclusion

The successful replication of meat-like flavor, texture, and appearance in plant-based burgers is a remarkable achievement in food science. Through biochemistry and advanced processing techniques, the food industry has bridged the sensory gap between plant-based meat and traditional meat. Key techniques such as the use of soy leghemoglobin for heme-like flavor, the controlled Maillard reaction for developing meaty aromas and flavor, and the high-moisture extrusion process for creating fibrous textures demonstrate how deeply biology, chemistry, and engineering are embedded to innovate from non-meat ingredients.

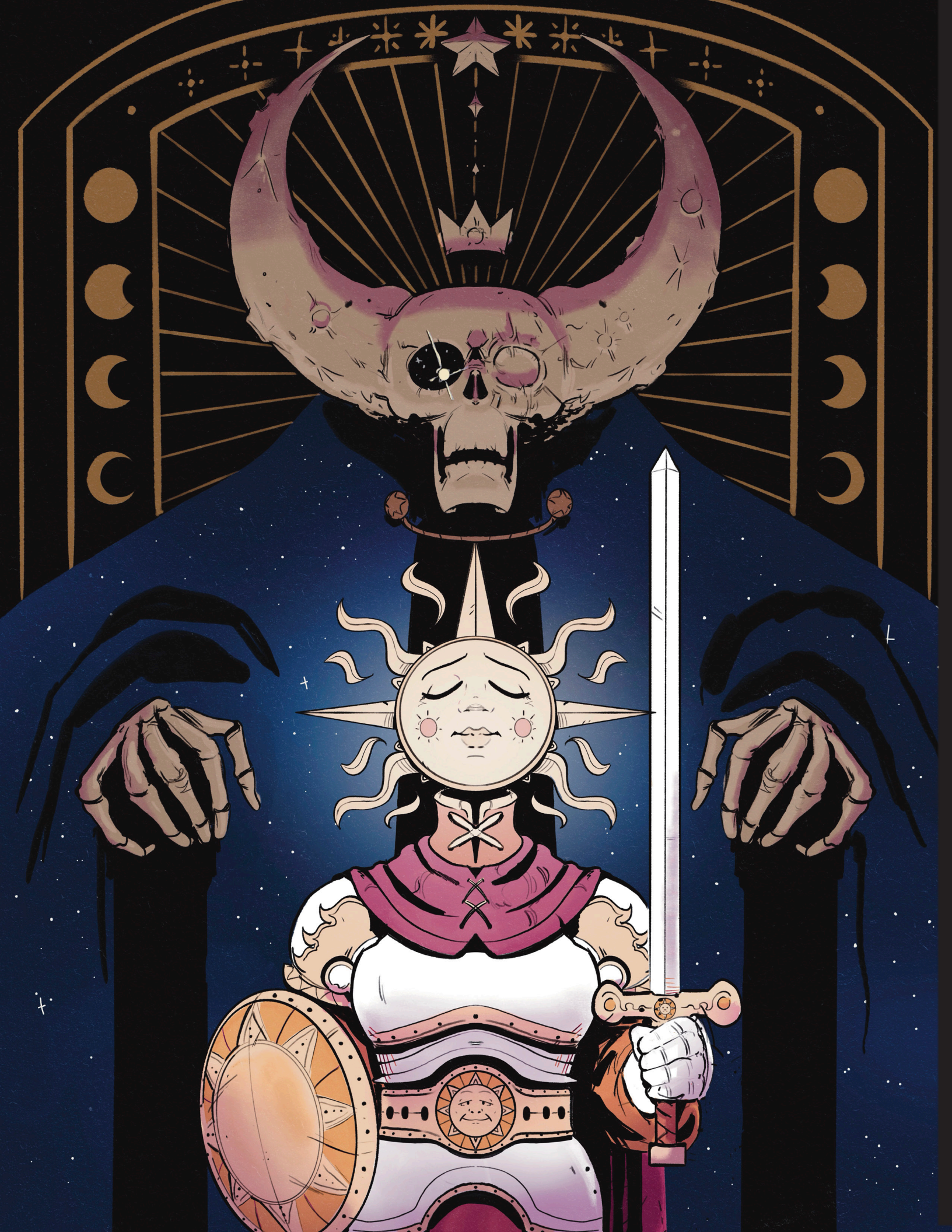
Although plant-based burgers are not necessarily the healthiest option as they are designed to match beef patties nutritionally and sensorially, PBB typically offer advantages such as higher fiber content and improved mineral profiles. These products are an inclusive option for consumers who avoid red meat for health, ethical, or spiritual reasons, allowing them to enjoy the familiar experience of eating a savory burger without compromise.

The technology behind plant-based burgers represents ongoing improvements by the food industry. A few decades ago, the concept of engineering the flavor and texture of plants to mimic meat would have been unthinkable and considered unnecessary. Nowadays, however, the increasing environmental impact of the meat industry cannot be ignored. Therefore, even a slight change in meat consumption serves as a meaningful step for environmental sustainability.

Annotated Bibliography

(1) Brunning, Andy. "Food Chemistry – The Maillard Reaction." Compound Interest, 27 Jan. 2015, www.compoundchem.com/2015/01/27/maillardreaction/.
This article gives a visual overview of the Maillard reaction and its significance in food flavor and browning effect. It provides a visual explanation of how sugars and amino acids interact to form complex flavors, which is important for understanding the generation of meat-like tastes in plant-based burgers.
(2) Chao, Chhychhy, et al. "Effect of L-Cysteine on Functional Properties and Fibrous Structure Formation of 3D-Printed Meat Analogs from Plant-Based Proteins." Food Chemistry, vol. 439, 1 May 2024, pp. 137972–137972, https://www.sciencedirect.com/science/article/abs/pii/S0308814623025906.
This study investigates how L-cysteine affects the structure of meat analogs. Based on the abstract, the study suggests that L-cysteine enhances fibrous texture formation, which improves sensory properties in plant-based meats.
(3) Costa-Catala, Judit, et al. "Comparative Assessment of the Nutritional Profile of Meat Products and Their Plant-Based Analogues." Nutrients, vol. 15, no. 12, 19 June 2023, https://pmc.ncbi.nlm.nih.gov/articles/PMC10305646/.
An analysis that compares nutritional differences between real meat and plant-based products. It finds that plant-based analogs generally contain similar fat and protein content to real meat burgers. PBBs have less cholesterol but are higher in saturated fats due to coconut oil.
Law 20
(4) De Marchi, M., Costa, A., Pozza, M., et al. "Detailed Characterization of Plant-Based Burgers." Scientific Reports, vol. 11, 2049, 2021, https://doi.org/10.1038/s41598-021-81684-9.
This study describes plant-based burgers by examining their chemical, physical, and sensory properties. The purpose of the investigation is to understand how plant-based options compare to meat in terms of texture, composition, and acceptability.
(5) Dopelt, Keren, et al. "Environmental Effects of the Livestock Industry: The Relationship between Knowledge, Attitudes, and Behavior among Students in Israel." International Journal of Environmental Research and Public Health, vol. 16, no. 8, 16 Apr. 2019, p. 1359, www.ncbi.nlm.nih.gov/pmc/articles/PMC6518108/
This study explores how students in Israel perceive the environmental impact of the livestock industry. Findings indicate that greater awareness of environmental issues can influence students to adopt more sustainable dietary choices.
(6) Fraser, Rachel Z., et al. "Safety Evaluation of Soy Leghemoglobin Protein Preparation Derived from Pichia Pastoris, Intended for Use as a Flavor Catalyst in Plant-Based Meat." International Journal of Toxicology, vol. 37, no. 3, 11 Apr. 2018, pp. 241–262, https://journals.sagepub.com/doi/10.1177/1091581818766318.
This article evaluates the safety of soy leghemoglobin, the heme ingredient of Impossible™ Burger that mimics meat flavor. It finally proves that the heme is safe for consumption.
Law 21
(7) Gao, Yang, et al. "Mechanism of L-Cysteine-Induced Fibrous Structural Changes of Soybean Protein at Different High-Moisture Extrusion Zones." International Journal of Biological Macromolecules, vol. 268, 15 Apr. 2024, p. 131621, https://www.sciencedirect.com/science/article/abs/pii/S0141813024024267.
Based on the abstract, this research probes how L-cysteine modifies soy protein texture during extrusion. It highlights the critical role of L-cysteine in enhancing meat-like fibrous structures.
(8) Jiang, Lianzhou, et al. "Improve the Fiber Structure and Texture Properties of Plant-Based Meat Analogues by Adjusting the Ratio of Soy Protein Isolate (SPI) to Wheat Gluten (WG)." Food Chemistry: X, vol. 24, 4 Nov. 2024, p. 101962, www.sciencedirect.com/science/article/pii/S2590157524008502.
This study tests how different protein ratios affect texture in plant-based meats. Highlighting the relation between soy protein isolate (SPI) and wheat gluten (WG), because when balanced, they enhance the fiber development and chewiness.
(9) Liu, Shuyun, et al. "Insights into Flavor and Key Influencing Factors of Maillard Reaction Products: A Recent Update." Frontiers in Nutrition, vol. 9, 12 Sep. 2022, https://pmc.ncbi.nlm.nih.gov/articles/PMC9511141/.
This article reviews the latest findings on Maillard reaction products and their role in flavor development. The study identifies the factors and ratios that affect flavor intensity and profile.
Law 22
(10) Schmid, Eva-Maria, et al. "High Moisture Extrusion Cooking of Meat Analogs: A Review of Mechanisms of Protein Texturization." Comprehensive Reviews in Food Science and Food Safety, vol. 21, no. 6, 19 Sep. 2022, pp. 4573–4609, https://ift.onlinelibrary.wiley.com/doi/10.1111/1541-4337.13030.
This investigation demonstrates how high-moisture extrusion gives plant proteins a fibrous, meat-like structure. The authors describe the physical and chemical transformations occurring during extrusion, including an explanation on the extruder processing zones.
(11) Sun, Ao, et al. "Maillard Reaction of Food-Derived Peptides as a Potential Route to Generate Meat Flavor Compounds: A Review." Food Research International, vol. 151, Jan. 2022, p. 110823, https://doi.org/10.1016/j.foodres.2021.110823.
The authors discuss how peptides from food sources undergo Maillard reactions to generate meat-like flavors. Also, emphasizing the potential of controlled peptide reactions to simulate meaty and barbecue flavors.
(12) Wolf, Julie. "The Microbial Reasons Why the Impossible Burger Tastes so Good." ASM.org, 16 May 2019, https://asm.org/articles/2019/may/the-microbial-reasons-why-the-impossible-burger-ta
This article explains the microbial science behind the flavor of Impossible™ Burger. It highlights how genetically engineered yeast produces soy leghemoglobin for industrial production.

Artwork: *Mighty Rex* by Lori A Rhodes



Jack of Hearts

Zephren J. Nyxa

I remember the first time I saw you, eyes wide and nervous, we warmed up to each other immediately. I tried to tell you, so many times I attempted to warn you of danger. But you recognized something in me, but all he saw was your bleeding heart. And like a predator he was on the hunt ever since. Neither of us knew it then, but we were doomed from the start.

You fought so hard to protect the three of us, it had been ages since I'd seen someone so determined to challenge him, despite his cruel demeanor. Never again will we witness a person battle furiously for our health and well-being. From this point forward, neither of us will be able to comfort your greatest in times of need. The plan of escape you had for us dissolved into thin air, we were so close too. Sweet child, no amount of love would have been enough to make him a good person. There's no saving that kind of evil, you should have left us the first chance you got. He never loved any of us, his core was tainted from the moment of conception. There was no way of fixing things, I knew things were bad, but not to this extent. It wasn't until I saw it with my own eyes, that I understood the type of pain he forced you to endure. I felt your tremors as I tried to stop the shaking, smelled the blood on your clothes. I remember the way you'd pat my head gently as you cried, hoping he'd change for the better someday. As the months went by, a sickness inside my brain began to eat me alive. Even though it took the vision in my right eye, I could still see that cancerous things don't only kill from within. Even when your voice cracked, your heart shattered, you still had the will to stand up for us.

I remember the last time I saw you on this side of the veil. I recall how your Halloween lights gave the whole room a soft lilac glow. But when you turned to face me, I saw how sunken in your eyes were, I knew then something terrible was going to happen. When I looked into them, it was clear you had floated off somewhere. Hidden behind that thousand yard stare. I had come to say my final goodbye, and found that he had already chased you from your body. You had become completely numb, so I returned upstairs and that was the final time we saw each other on the same plane of existence. As I struggled up the stairs, I found myself disgusted with the way he looked at me. He had no shame, not even allowing you to give me something for the pain. You tried of course, but to no avail. As I walked back into the room, I took one last glance in the mirror and didn't recognize the cat staring back at me. My green eyes, once so full of life, now dull. My midnight coat which used to be so thick and shiny, was now patchy and flea ridden. My legs, which had carried me high and far, now were too weak to budge. Never have I felt so heavy and weighed so little, all my bones protruded outwards in ways they hadn't before. It had been days since I was able to keep down food or water, I knew it wouldn't be long now.

That night, when Death came for me, I asked where you had gone. My spirit sank through the floor and found its cloaked figure kneeling beside you. I watched as the gloved hand delicately wove its fingers through yours before declaring that you were slowly losing the will to live. My heart skipped a beat when I saw you stir, but the excitement quickly ended when I realized you were having a nightmare. I tried waking you up, I hopped up onto your chest like I always used to when you were melancholy. When I asked again where you were, Death said your soul was hiding because your vessel was preparing for war. Somehow you had unlocked separating the body and mind from one another. Even showed me your future, one week from today, I saw what happened to you.

I saw how he robotically shoved you into the mattress for a couple minutes before quickly leaving without saying a single word. Dear one, your eyes never left the tv, I know you were watching the important documentary about the man with the butterfly sanctuary. Death told me how in that moment you wished for wings to fly as fast away as you possibly could. That much was clear, your tears soaked the sheets. As you silently wept, something inside of me knew that this was just the beginning of the end.

Your soul was still out there, and if it wasn't guided back to your body before you died, then it would be stuck in limbo forever. As I contemplated Death's words, a gentle orange glow of the fireplace suddenly illuminated the room. I turned to find you and the kittens wrapped in blankets, trying to keep warm, an old memory. As I perch onto the lazy boy, I realize I don't weigh anything. My body doesn't make any indentations, when I look at my legs I noticed that they don't hurt at all. Nothing does anymore. I watched as my past self jumped onto your lap and joined the kittens. I couldn't help but notice the flickering light of the fire reflecting in your tears as you began to cry. You'd always begin to cry if you looked at me too long, ever since that terrible vet visit. In that moment you smiled down at me and said that no matter what happened, that you'd always carry the three of us in your heart.

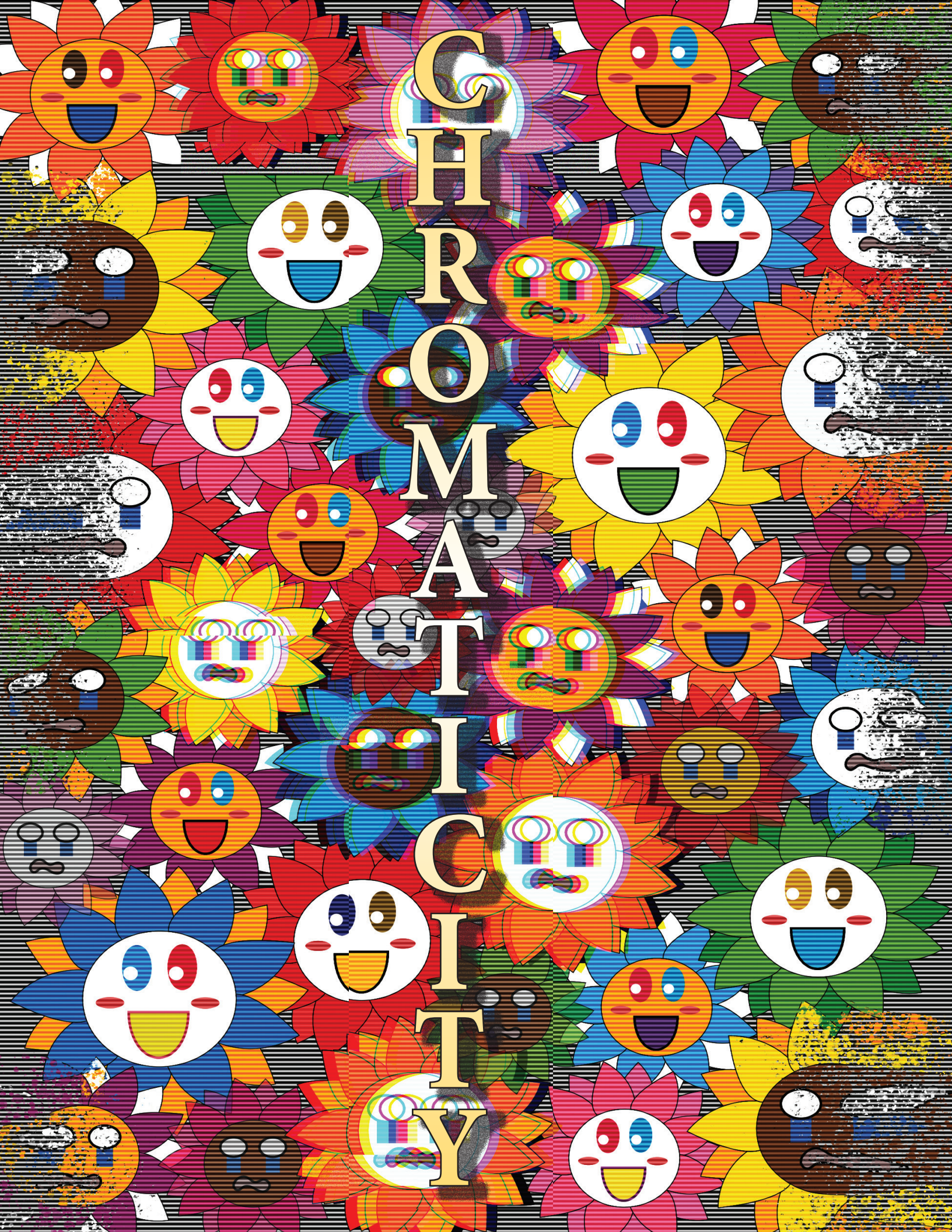
I glanced over at the kittens, recalling how annoyed I was when they first arrived. They had come with many promises of change, broken, jagged ones. But the two of them eventually grew on me, I guess you could say even warmed my heart. They were such a pain in my ass, but I loved them in the end. The both of them were near in my final moments, they made sure I didn't feel alone. As rambunctious as they were, they were also loving and determined despite my grumpiness. They were unexpected, but what I needed when Death finally came for me. I will miss them dearly.

The Halloween lights flickered violently as Death hovered over to the mattress. The fur on my back stood up as I saw it reach for you. As I made my way over, I was told you'd be awarded one final kindness before allowing me to reunite your body and soul. And with the wave of a hand, you stirred at last and I was able to bump foreheads with you! I hope that my last purr for you is healing enough to last, I know how your folks would never allow you to keep a cat. Remember me healthy, like when we first met okay? I'll miss you always and promise to watch over the kittens. Stay strong, don't ever allow the pain they inflict to dishearten you.

"Goodnight, my Jack of Hearts."

Death scooped me up from the bed, but I made sure not to look away as your eyes fluttered closed. I was told that if you remembered anything at all, it would be like a dream. I'll always remember the way you smiled at me when you said my name. Thank you, for loving me.

Artwork: *Sun Knight the Crescent King* by Tyber Savin


CHROMATICITY

Artwork: *Night at the Fusion Stand* by Tyber Savin

Artwork: *Nothing Stays in Bloom* by Lindsy Hertanu

Transnational Border Crossings: The Arrival and Guantanamo Kid

Phượng Hoàng

Shaun Tan's The Arrival (2006) and Jerome Tubiana and Alexandre Franc's Guantanamo Kid (2019) are both graphic novels featuring stories of transnational border crossings, but the two books suggest very different ways of thinking about borders, about how and why people cross them, and to what effect. In this essay, I will discuss how these two texts engage the dialectic between structural power and individual agency within different types of border crossings.

Structural power surrounds us. It is literally most everywhere we are: psychological norms that delineate how we perceive ourselves, societal values that prescribe how we interact with others, economic baselines that classify financial status, political scaffoldings that characterize how we interact with those inside and outside our policy beliefs. But I would posit that precisely because it is literally most everywhere we are that individual agency is possible because we are at its center.

Individual agency is innately within us. It is us: as humans we are each endowed with individual self-determination, interpretative capacity, and values. Agency can take many forms and can be whatever we creatively construct and willingly execute. Taking many names, agency is synonymous with – among others – Audre Lorde's "militancy", Gloria Anzuldua's "crossroads", Grace M. Cho's "teum[-] unguarded moments", Kale Bantigue Fajardo's "contact zones", Mark Redondo Villegas' "repertoire", and Gerald Vizenor's "survivance[-] sui generis sovereignty". In all its forms, agency is fundamentally fungible and contains a malleability that can empower the individual. Its fungibility allows for the re-shaping, re-formation, cross-pollination, and integration of any singular or combination of methods that can deconstruct structural power.

Though there is a difference between Tan's protagonist's border crossing and that of Mohammed El-Gharani, they both share "militancy" as a form of agency. In the former, Tan's protagonist makes a voluntary decision to leave his family in search of better opportunities (Tan Chapter I). In the latter, Mohammed El-Gharani is captured by the Pakistani police and sold to the U.S. military (Tubiana & Franc 23-25). In both cases, "militancy" is applied, though very differently. While "militancy" is conventionally described as "the use of confrontational or violent methods in support of a political or social cause"[1], this colonial definition is used by the structural power embodied by Tan's pointed tentacular creature constantly hovering in the shadows and by the Pakistani police and the U.S. military respectively (Tan Chapter I, Tubiana & Franc 23, 29).

However, "militancy" also possesses a post-colonial component advanced by Audre Lorde who codified it as demeanors "actively working for change, sometimes in the absence of any surety that change is coming"[2] and this is the militancy utilized by the protagonists in both narratives. For the unnamed protagonist, his agency is inspired by a militant and deep-seated desire to free himself and his family from oppression (Tan Chapter I). For El-Gharani, his agency stems from a militant belief in religious and spiritual values that foment resistance, tenacity, and conviction (Tubiana & Franc 62, 84-85). They both champion a militancy opposite in value but equal in potency to their oppressors', a non-violent self-determined militancy that is emboldened by an overwhelming sense of truth and duty, a passionate commitment to self, family, and values, undergirded by a profoundly unshakable faith in humanity.

[1] www.dictionary.com

[2] Audre Lorde "Learning from the 60s" Speech at Harvard University in February 1982.

Both protagonists' faith is well-founded because it is through their militancy that they are able to "survive [and overcome] the Borderlands", "live sin fronteras", and "be a crossroads" that transcend the material constructs of colonial "border[lands]" that attempt to restrict, confine, and define them (Anzaldua 217). They defy "borders" and "crossings" as typical modern conceptualizations that are objective-dependent, directionally-limited, and positionally-confining constructs and, instead – like Anzuldua – reframe the structure "to envision the impact of the material border in less degrading and more sustainable ways" (Brady 35). Through this metaphoricity, they broaden the conceptualization of the material border as something more than a linear demarcation between two nation states and transform it into a space of occupation that is a frontera or borderlands where they "can embrace multiple contradictions and refuse the impossible effort to synthesize them fully, thus turning apparent oppositions into sources of insight and personal strength" (Brady 35).

Moments where both protagonists turn "apparent oppositions into sources of insight and personal strength" abound throughout the duration of their ordeals. For Tan's protagonist, they surface as borders created by differences in language, culture, and affinities while for El-Gharani, borders are personified through hierarchy and state-sanctioned action (Tan Chapters II, III, Tubiana & Franc 43- 46, 57, 66, 70, 103). Nevertheless, both protagonists look beyond the physical and material constructs of "borders" to see commonality with the non-self and recognize that the non-self "do[es] not have to be me in order for us to fight alongside each other [] What we must do is commit ourselves to some future that can include each other and to work toward that future with the particular strengths of our individual identities. And in order to do this, we must allow each other our differences at the same time as we recognize our sameness."[3] This ability to identify common ground despite their differences becomes a basis for the goal-defining exercise of working towards a joint future and exemplifies the intersection designated by Kale Bantigue Fajardo as "contact zones" where dominant state narratives are countered by the personal experiences and self-determination of the individual participants (Fajardo 405). These contact zones become what Grace M. Cho termed "unguarded moments" where travelers tread paths that play out "[in time or] in teum [in conjunction with] the imperceptible spaces in between" (Cho 165).

Tan's protagonist positivizes these contact zones by appealing to the non-self on a basic human level. With the first stranger, he appeals to his human need for shelter; with the stranger on the ship, he appeals to her human need for sympathy; with the father and son, he appeals to their human need for security, needs that are universally recognized as necessary and essential to human wellbeing (Tan Chapters II, III). By appealing to the non-self on a personal, elemental, and often emotional, level, the protagonist's interactions do not follow the colonial paradigm of classifying these non-selves as "others" but as extensions of the self and generate narratives that counter master narratives dislodging the myth that a person who speaks another language, comes from another culture, or holds different beliefs are foreigners who do not belong. These moments of human connection are the "imperceptible spaces in between" left "unguarded" by the master narrative where individual agency can dismantle structural power. By aligning himself with the non-self,

the protagonist and his "contact zones" (the man, woman, father and son) have developed a joint narrative that consubstantiates their convergence to birth a new discourse, one outside and separate from the dictates of the master narrative.

[3] Audre Lorde "Learning from the 60s" Speech at Harvard University in February 1982.

Likewise, El-Gharani also infuses his contact zones with positivism as he interacts with the non-self as embodied by the Pakistani and U.S. guards, Mike Tyson, Chocolate City, and the Mexican S.O.G. El-Gharani astoundingly appropriates the master narrative to convert the non-self into a version of self (Tubiana & Franc 27, 57-59, 71, 76). This appropriation is most powerfully seen in his interaction with Mike Tyson who, not only refuses to abuse El-Gharani, purposely disobeys direct orders, risks insubordination, gambles dismissal, and endangers his political career, but "convert[s] to Islam and [left] the army" (Tubiana & Franc 58-59). Indeed, El-Gharani is so masterful that, akin to Geo, he also uses "repertoire" with "performative [] cultural expressions" by writing his first poem, singing "No. 2"/"Stand Up for Your Rights", and seizing those "unguarded moments" to create intersections, "provide a racial discourse", inspire resolve, and birth new contact zones (Villegas 26, Tubiana & Franc 27, 54, 75).

As fungible methodology, individual agency can also take the forms of Gerald Vizenor's "survivance" and "sui generis sovereignty". In addition to using the forms of agency noted above, both Tan's protagonist and El-Gharani, as emissaries of the oppressed, further overcame colonialism's overbearingly long reach by employing "a 'sense of native motion and an active presence' that is recognized by 'survivance, a reciprocal use of nature, not a monotheistic, territorial sovereignty'" to create and thrive in a self-defined modernity (Lyons 5). Formerly a legal term that fell into dis-use, "survivance" was revived and re-contextualized in contemporary Native American studies to mean "an active sense of presence, the continuance of native stories, not a mere reaction, or a survivable name. Native survivance stories are renunciations of dominance, tragedy and victimry".[4] Survivance is therefore "the condition of self-reliant or communal survival without the social or personal indulgence of victimization".[5]

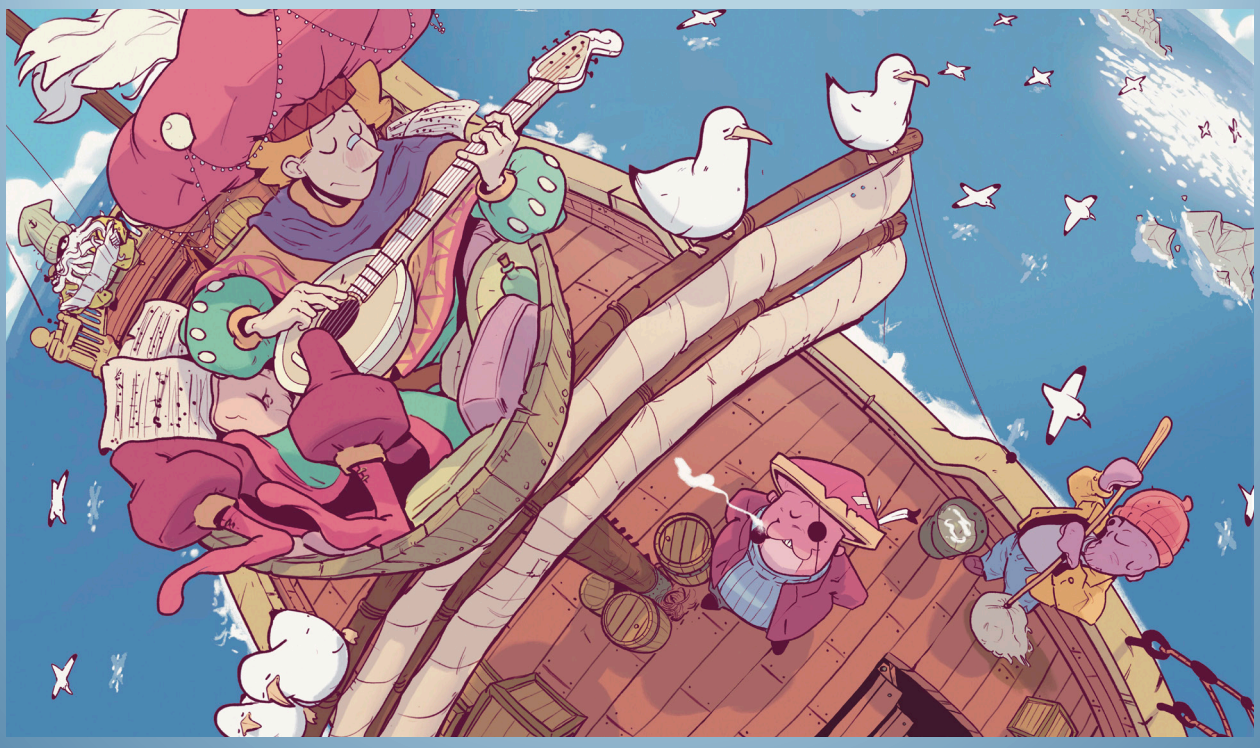
Both Tan's protagonist and El-Gharani appropriated their narratives through the contextualization and construction of a diametrically self- and communal-reliant paradigm that excluded social and personal indulgences of victimization by appealing directly to the humanity within their non-self contact zones. Renouncing dominance, tragedy, and victimry, they bypass the borders created by structural power and call upon a "sui generis sovereignty" to (re)/produce and own their "creation stories, totemic visions, reincarnation, and sovenance" (Lyons 5). Originally a Latin phrase, "sui generis" means "'of its/his/her/their own kind, in a class by itself', therefore 'unique'" while "sovereignty" means "supreme power or authority", "the authority of a state to govern itself" or "a self-governing state".[6] Therefore, this transmotion is a "self-governing state that is in a class by itself" or, put differently, it is the condition of governing oneself defined by one's own unique positionality that requires neither state sanction nor class categorization.

Militant transmotion borne from the convergence of particular contact zones where each self shapes, forms, cross-pollinates, and integrates the non-self through communal exchanges inevitably disrupt master narratives and dismantle structural power. Serving as crossroads, both Tan's protagaonist and El-Gharani move the self and the non-self – together – towards radical new possibilities mined from the shared "unguarded moments" and the "imperceptible spaces in between" to ultimately encompass and enrich both selves by depending upon and deepening each self's humanity.

[4] Gerald Vizenor, Manifest Manners: Narratives on Postindian Survivance, Lincoln: Nebraska, 1999), p. vii.

[5] Joe Lockard, "Facing the Windiigoo," in Survivance: Narratives of Native Presence, ed. Gerald Vizenor (Lincoln: Nebraska UP, 2008), p. 210.

[6] www.dictionary.com



Artwork: A Song for the Voyage by Tyber Savin

Photo: Light and Shadow 2 by Albert Lau

On Late Capitalism and Cheese
Libby Oren

Sometimes we write just to write
With the weird cheese and misconstrued sentences like
Who is doing the assuming, the manipulating
Carving unyielding blocks of Brie into bite sized bits so everyone can taste them for 6.99 or
Worse, prepackaged parcelling, doling out unserious circles of archaic confection in
Whole Foods or Trader Joe's, in Safeway or Berkeley bowl like little political embraces
It's safe here, they say, it's easy,
Our aisles are stocked with every nature of decorated delicacy, pears and peaches in off season earthen hues, we are a supermarket of embrace,
Of late style, humanism unkempt,
A world where everyone is on time and toted around in torn up shopping bags, there
Is nothing rotten here, no murder to misrepresent, no schema of uncertainty, we
Allow your wonderings,
Sometimes we sell nothing at all, vapid air
Fills shopping carts, their hearts a hopeless hurricane of money and mutterings
Sometimes we sell it all, bookstores with closed doors and signs that slowly tick higher, liquidation discounts and barred doors, eventually, the brown waxed paper on glass windows that comes for us in the end,
We are always on time
In a world which doesn't allow for the dilly dally, for the imperfect, for the sentences mismatched and oddity unwound, we whisper of
Unease, inconvenient, a day spent sleeping in peace
We whisper
You'll be next

Parkinson's Disease Handwriting Patterns: A Directional Analysis

Brian Young

1. Introduction

Being able to write is a privilege many people may take for granted in our everyday lives. Having impaired handwriting leads to a drastic effect on the quality of life of people with Parkinson's disease (PD). While researching PD and handwriting, I found a gap in the current literature: there has not been an analysis differentiating between the direction of movement in diagonal or circular patterns compared to straight lines. Moreover, there has not been analysis done comparing diagonal lines to each other. Previous studies (Thomas et al., 2017; Ma et al., 2013) suggest that horizontal writing strokes demonstrate a marked decrease in amplitude (micrographia) due to the high cognitive and motor load of moving across the page, while vertical strokes remain relatively preserved. However, this "x-axis vs. y-axis" idea ignores critical directions of movement: the diagonal and the spiral.

In the natural anatomy of the human hand, writing is rarely purely vertical or horizontal; it is a series of curved and diagonal movements that require complex coordination of the wrist flexors (flexor carpi radialis/ulnaris) and extensors (extensor carpi radialis/ulnaris). Through my observations as a coach at Rock Steady Boxing (a non-contact boxing program for PD patients), I noted that rigidity often appeared asymmetrical depending on whether a patient was extending or flexing their arm. This observation led to my central research question: Does the direction of movement affect the severity of dysgraphia? If so, how does wrist extension and flexion play a role in this? I examine the "Wrist Flexion Hypothesis": that handwriting impairment in PD is not uniform but is exacerbated when the stroke requires increasingly more wrist flexion (bringing palm closer to forearm). This project aims to quantify this phenomenon by mathematically modeling handwriting accuracy across varied directional vectors.

2. Methodology

2.1 Participant Selection I conducted this study with a cohort of 19 individuals diagnosed with Parkinson's disease recruited from the Rock Steady Boxing program. This setting provided a unique advantage: the participants were physically active and engaged, yet presented with varying stages of neurodegeneration. Crucially, 47.4% (n=9) of the participants self-reported experiencing dysgraphia. This allowed me to split the data and perform a comparative analysis between the symptomatic subgroup and the general PD cohort.

2.2 Task Design To isolate the variable of directionality, I replaced standard "sentence writing" tasks, which introduce linguistic cognitive load, with a geometric tracing task focused purely on motor kinematics. I utilized LaTeX and the pgfplots package to generate precise, worksheet templates containing four tasks (see Figure 1):

1) Horizontal Line: Testing lateral wrist deviation.
2) Archimedean Spiral: Modeled by the polar equation r() =+k. This shape requires continuous, synchronized changes in both the x and y coordinates.
3) Diagonal Up (+m): Requiring wrist extension.
4) Diagonal Down (-m): Requiring wrist flexion.

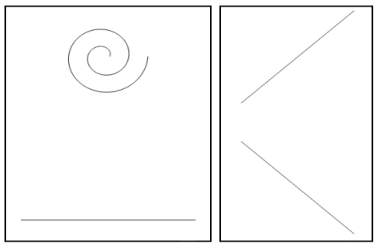


Figure 1: Worksheet Template

2.3 The Measurement Problem and Solution A significant challenge in this research was the lack of access to digitized tablets or kinematic sensors. To overcome this, I engineered a manual measurement system based on variable tolerance zones. I created transparency overlays printed with concentric tolerance zones relative to the template line. These zones were calibrated such that each interval represented a 2mm displacement (see Figure 2).

1) Zone A: 0–2 mm deviation (High Accuracy)
2) Zone B: 2–4 mm deviation (Moderate Accuracy)
3) Zone C: 4–6 mm deviation (Low Accuracy)

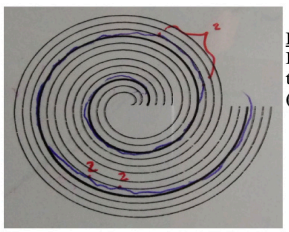


Figure 2: Example of transparency use (Patient ID: 0661)

To quantify handwriting quality, I derived a weighted percentage accuracy metric (P%). Recognizing that simply summing the length of the line would be insufficient, I utilized a formula to penalize deviation:

Equation 1: P% calculation

$$P\% = \frac{T - (W_1 \cdot d_{2-4} + W_2 \cdot d_{4-6})}{T} \times 100$$

Where T is the total arc length of the stroke, and d represents the length of the stroke falling within the specified error margin.

3. Results

3.1 Overall Cohort Performance The initial data analysis revealed that the overall cohort maintained a high level of accuracy, with a mean P% > 94 across all tasks. This high baseline may be attributable to the participants' engagement in boxing therapy, which requires high-intensity hand-eye coordination. However, when isolating the subgroup of participants who self-reported dysgraphia, distinct patterns emerged.

3.2 The Diagonal Divergence

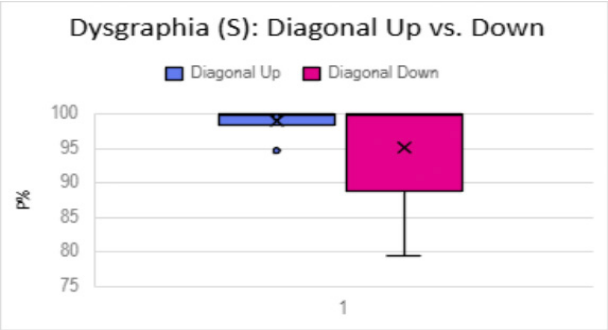


Figure 3: Box plot of data for symptomatic cohort. represents the mean; black bars represent IQR; dots represent outliers; graph starts at P% = 75. The most critical finding of this study appeared in the comparison of the two diagonal vectors for participants who are symptomatic for dysgraphia (see Figure 3). Hypothesis testing (paired t-tests) between the "Diagonal Up" and "Diagonal Down" tasks yielded a p-value of 0.078. While this falls outside the standard alpha of 0.05 for statistical significance, it represents a strong statistical trend given the small sample size (n=9 for the symptomatic group).

3.3 Qualitative Kinetic Analysis

Visual inspection of the samples supported the quantitative data. Through analyzing Figure 4A, we can observe that the writing quality starts out well in the center, but as the participant starts drawing outwards towards the left side of the template, writing quality becomes worse. Additionally, when analyzing the diagonal lines (Figures 4B and 4C), we can observe that the writing quality in the Diagonal Up sample is better than the writing quality of the Diagonal Down sample.

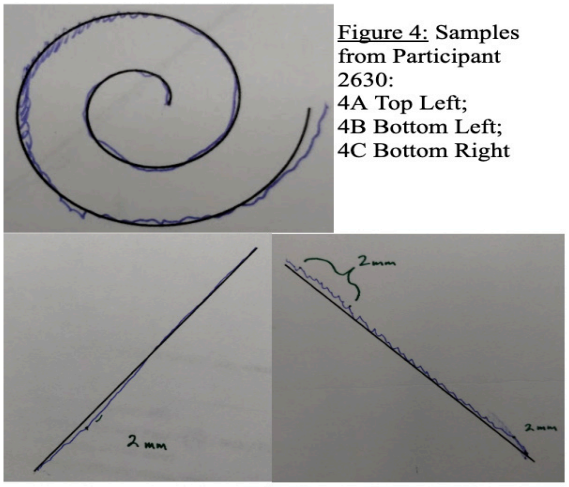


Figure 4: Samples from Participant 2630:
4A Top Left;
4B Bottom Left;
4C Bottom Right

4. Discussion

4.1 Biomechanical Implications These findings challenge the assumption that handwriting therapy should focus solely on "writing bigger" (a common cue for micrographia). Instead, my data suggests that therapy should focus on directional training. If downward movements are indeed the point of failure, patients may benefit from rotating their paper or altering their grip to convert flexor movements into extensor movements, thereby bypassing the motor deficit.

4.2 Limitations of Methodology While the transparency overlay system was an innovative solution to a resource constraint, it introduced uncertainty by relying on human judgements. Furthermore, static analysis (looking at the ink after it dries) fails to capture temporal dynamics. A patient might trace a perfect spiral but take 60 seconds to do so. My current P% metric treats a slow, perfect line the same as a fast, perfect line, masking the true neurological cost of the movement.

4.3 Future Research I propose a follow up study utilizing digitized tablets and a higher sample size. This would allow for the capture of temporal variables (velocity and acceleration) and axial pen pressure, likely yielding statistical significance ($p < 0.05$).

5. Conclusion

This study serves as a pivotal marking point for future research to investigate the "Wrist Flexion Hypothesis." Parkinson's disease dysgraphia stands as the second most prevalent symptom of the disease, and by prioritizing the study of directional handwriting patterns, we can move toward more sophisticated diagnostic tools and practical, everyday interventions that restore agency to those living with Parkinson's.

References

Drotár, P., Mekyska, J., Rektorová, I., Masarová, L., Smékal, Z., & Faundez-Zanuy, M. (2016). Evaluation of handwriting kinematics and pressure for differential diagnosis of Parkinson's disease. Artificial Intelligence in Medicine, 67, 39–46. https://doi.org/10.1016/j.artmed.2016.01.004

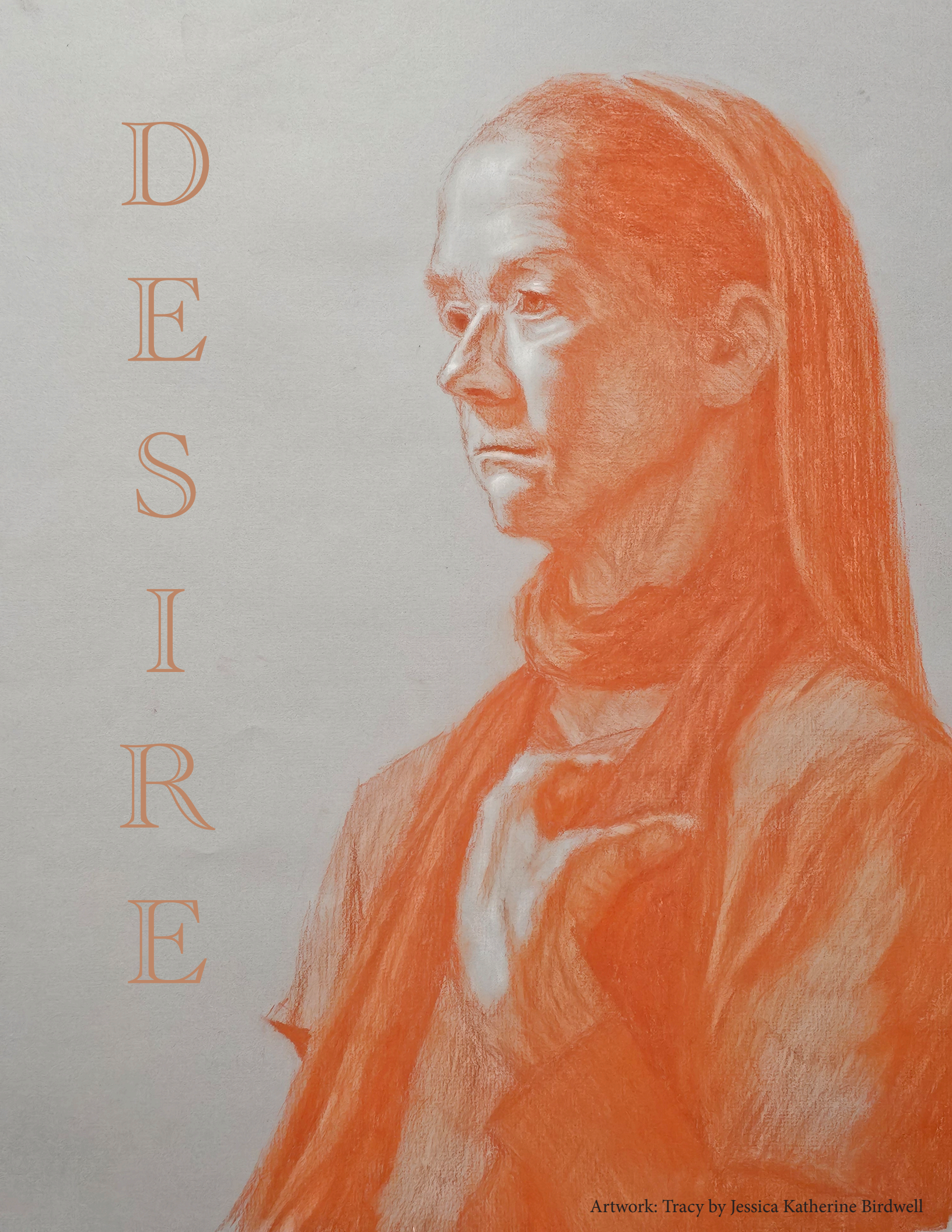
Ma, H.-I., Hwang, W. J., Chang, S. H., & Wang, T.-Y. (2013). Progressive micrographia shown in horizontal, but not vertical, writing in Parkinson's disease. Behavioural Neurology, 27(2), 169–175. https://doi.org/10.3233/BEN-120285

Mucha, J., Karmele López-de-Ipiña, Faundez-Zanuy, M., Jiri Mekyska, Vojtech Zvoncak, Galaz, Z., Kiska, T., Zdenek Smekal, Lubos Brabenec, & Rektorová, I. (2019). Analysis of Parkinson's Disease Dysgraphia Based on Optimized Fractional Order Derivative Features. European Signal Processing Conference. https://doi.org/10.23919/eusipco.2019.8903088

Thomas, M., Lenka, A., & Kumar Pal, P. (2017). Handwriting Analysis in Parkinson's. Movement Disorders Clinical Practice, 4(6), 806–818. https://doi.org/10.1002/mdc3.12552

Artwork: Distortion by Brian Youny

DESIRE

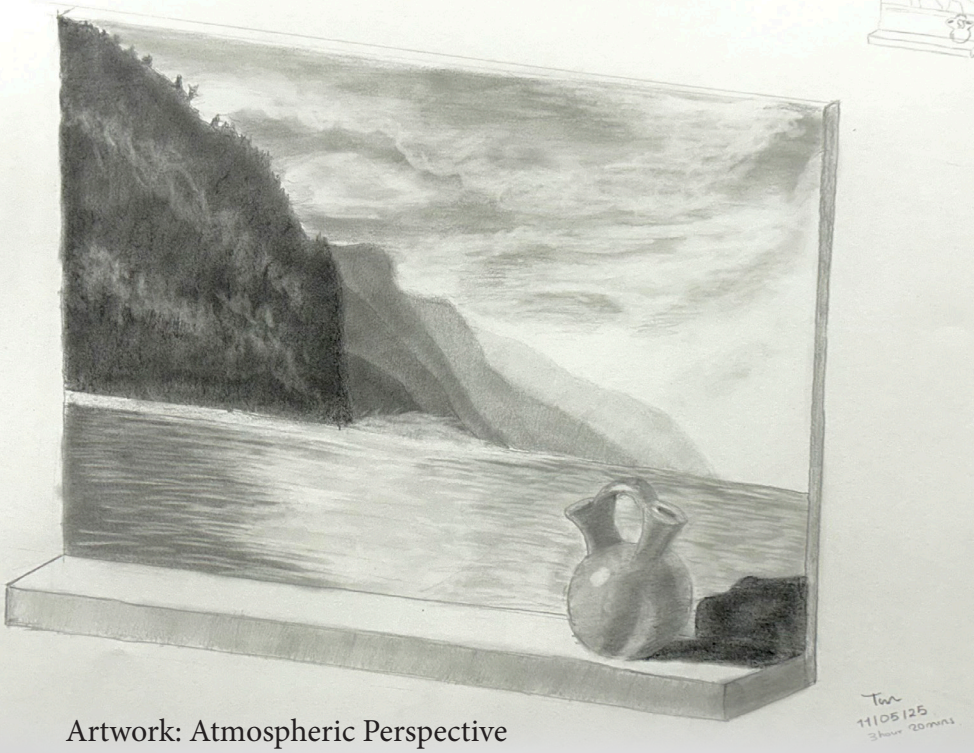


Artwork: Tracy by Jessica Katherine Birdwell

Dysania, After A. Van Jordan's Afterglow

Ocena Wilberg

Dy sa ni a n. 1. A chronic inability to rise from bed on those days when it's only the same life repeating all over again. 2. A desire not to be awake, to drown in sleep and live a dream: if I could dream this life away / This whispered caress on my back, / This name remembered by the tip of my lips / This tinny music in a lightless bathroom / This lidless white coffin for my thoughts / Whirlpool of severed selves / This dying light through the blinds / This tentative bedroom door / This burdened body, / This fragile mind / These starving memories prowling, / Foreboding / This specter of the future / This frantic midnight vigil against yet another day / This flight from my being / While every new dawn, / The depths recede / Wax wings wane / And I'm only the same person / falling all over again.



Artwork: Atmospheric Perspective
by Tin Thiri May

Line Dancing

Libby Oren

We dance unquiet conquest
lesbian lovers under installed moonlights
silicone stars on studded walls
late night is when these boots get tapping, two step turning,
follows fall curved into open leader limbs poetry all
a mess
arms and spinning legs long and elegant
listening to same songs over and over again, these melodies a rhapsody of rhythm
line dances memorized melancholy in every beat
bent out
sundance, stud, starlight, hotline in San Francisco this is being twenty two
is holding youth close to beating heart, strong arms and lifting off of tapping toes,
rosemary in your car later, and learning

bodies, every dimpled indent of my anxious bones,
stumbling missteps and coughing dry, waltzing wrong and
west coasting worse, two step only passable when trapped into monotony,
the bars become cages, rigidity felt in nervous body uncrackable
nothing underneath

DUPLEX DUPLEX

Jasmine Aylsworth
a duplex accommodates two people

The address: divided, undefined
She is a decade memorized zipcode

Eternal tenant, every scream, tear, and laugh
Concrete philia, an unwavering testament

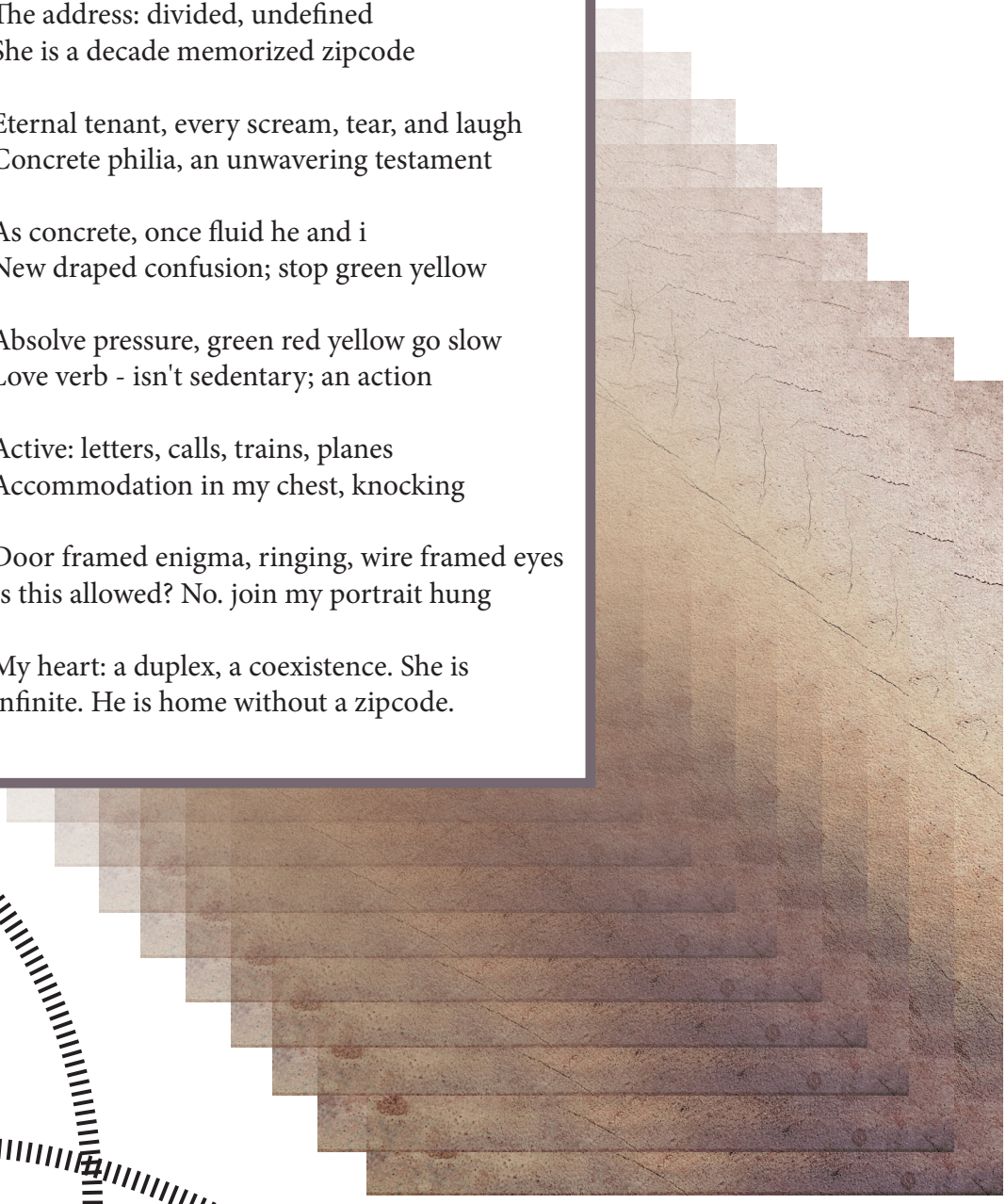
As concrete, once fluid he and i
New draped confusion; stop green yellow

Absolve pressure, green red yellow go slow
Love verb - isn't sedentary; an action

Active: letters, calls, trains, planes
Accommodation in my chest, knocking

Door framed enigma, ringing, wire framed eyes
Is this allowed? No. join my portrait hung

My heart: a duplex, a coexistence. She is
infinite. He is home without a zipcode.



Painted Horses

Natalia Villegas-Castillo

I'm a paint filly named Summer
Just like the season
Two stalls down is Shasta, my mother
Who is too weak to talk to me, but I don't know the reason

I don't ever get to spend time with my mom
I often think about her on my walks in the forest
When I get too sad, I do my best to stay calm
Spirits of The People bring me comfort, the ones before conquest

They sing me songs of their ancestors while they braid my mane
And tell me tales of how our kin once fought side by side
Often praying someday the evil within Sue and Shawn will go away
The children bring me hope, despite hearing whispers about the horror of their crimes

The older ones tell me that they understand our pain
How once, they saw my mom buckle at the knees while being worked to death in the sun
The elders would often say that in another life we might have lived peacefully in the grassy plains
And that they would be waiting for us when our day comes

In my dreams, together we fight our oppressors, just like before
And we roam free without worry, soaring across the earth
I don't wonder why my mother won't talk to me anymore
I'm not even sure she recalls me or ever giving birth

When I miss my mom, what I remember most are the color of her eyes
Bright and blue they are
Just like cloudless summer skies
I wait for the day we can truly be reunited, so together we can finally fly

I know once, horses were cherished and respected
I just wished we lived in a time we were better protected

Dedicated to all the afflicted Bay Area Equines of Chaparral Ranch

On the Ethics of Breathing

Brenna Patton

You slept in my arms,
While I slept on the floor.
The tile is cool and glossy,
Littered with broken glass from busted bulbs

My skin is hot,
My back hurts,
And my lungs are starting to ache.

The bed sits soiled,
Infested with mites.
I boarded the windows
Because you said the sun was too bright
And locked the door to keep out the night

Days and dates lose their meaning
Trapped in this rotting room,
Mold grows on our peeling walls,
Suffocated, I grow sleepy.

But your breath is clean–
Free from the spores
Growing in my rib cage.

Please, keep breathing.
Your breath is mine
As I follow the rhythm.
The sharp inhale-
the slow exhale–
In, out, then in again
consoling my constricting chest.

The corners of my mouth
split in decay
hovering over yours,

The air,
toxic and humid.
Your breath,
Sweet and lucid.

As it invades my lungs.
Expanding, straining,
Spinning, and spilling.

So please, more–
I just need a little bit more,

There is little I can give you,
My eyes are drooping,
While maggots crawl at my legs.
My skin will soon decompose.

You wore my hair on your head,
When yours started to fall out.
And this rot has fused my hand to your cheek

But feel free
To have my heart
And take my lungs.
All I need is one last gasp.

But your body is cool,

Your eyes–
are glossy.

The Homogenous Psychology of Romantic and Platonic Relationships

Bella Ingrao

Romantic and platonic relationships share many characteristics, especially through a psychological perspective. By diving into different facets of these relationships, I uniquely analyze them by looking for similarities. As someone who has experienced her own version of the trope "friends to lovers" many times, I have seen the line of distinction between romantic and platonic feelings shrink and grow. As we all experience it so differently, it can be difficult to come to logical conclusions regarding the principles and defining factors of love. I began my research project examining the three types of love within cultures: romantic, platonic, and familial. As I am only one student conducting a community college independent research project, this was much too daunting of a task. To focus in and gain a deeper understanding, I decided to investigate the psychological similarities of romantic and platonic relationships.

THE SOCIAL CONSTRUCTION OF INTIMACY

Although not a commonly debated topic, similarities between romantic and platonic relationships are shocking. Despite the strong social division between how friendships and romantic relationships are perceived, this division was a fairly modern idea. In fact, the distinctions between romantic and platonic relationships only became as solid as they are today in the 18th century through the modern ideals of the Enlightenment. The Enlightenment was a European intellectual movement through which ideas of nature, science, reason, and humanity were transformed into widespread perspectives in the Western world. Many revolutionary sociologists and philosophers emerged from this movement. These people helped define romantic and platonic love as we know them today (Marriage, Brittanica). Marriage is a social and economic construct commonly associated with romantic love. In its origins, marriage was a transaction of the daughter of a family to become the mother of another. During many periods of time when women lacked autonomy, it was important for the man of the family to have authority over them. This is how marriage was viewed, as a transition of authority from the father of one family to the husband of another.

Defining Romantic and Platonic Love

Romantic love is commonly defined as a feeling of non-material attraction. Having feelings of romantic love and attraction towards someone, often means you are attracted to their personality as well as their physical self. Romantic love is an advanced form of human attraction correlated with the passion aspect of Sternberg's triangular theory of love: Intimacy, passion, and commitment. Essential components of romantic love are physical attraction and sensual feelings (Though, asexual romance is an exception.) Romantic relationships without attraction tend to lose their spark, making this a key element of commitment in a romantic relationship. (Toward a Comprehensive Theory of Love: The Quadruple Theory [Attraction, Connection, Trust, Respect]).

Platonic love is often defined as a fundamental part of long-term friendship (though not necessary). Despite lacking attraction, platonic love is nonetheless a deep affectionate bond between friends. It is a rudimentary aspect of living, in which humans find companionship and friendship that can last a lifetime. Due to the societal and sociological pressures of forming romantic attachments to the opposite sex, and platonic attachments to the same sex, when both attachments occur within relationships with both sexes, it can be hard to differentiate or discern the true meaning behind these feelings. The psychological grounds in which I plan to analyze the similarities and differences between romantic and platonic relationships are the physiology of each relationship, the duality of modern marriage as a romantic and platonic partnership, the behavioral characteristics, and personal experience struggling with this intangible divide.

I do not believe nor am I asserting that the two relationship types, romantic and platonic are the same in totality. I am only expressing their similarities through a psychological lens. In fact, the most distinctive differences between the two relationships are social and societal. The expectations pushed on interpersonal relationships through society influence them to a large degree. Through environmental factors, humans learn how they are expected to behave in certain relationships and situations. Without these expectations of behavior, certain unacceptable behaviors may be more tolerated or occur more publicly. In fact, from a sociological and biological perspective, the two are much less similar than they are psychologically.

PHYSIOLOGY OF ROMANTIC AND PLATONIC RELATIONSHIPS

When it comes to relationship physiology,

Photo: Gone Fishing by Maria McCambridge

romantic and platonic relationships share many of the same characteristics. Due to biological influences on our relationships, physiological reinforcements that cause people to develop relationships remain the same in both types of relationships. This is because social behavior is driven significantly by reinforcements. For example, Oxytocin or "OT" is a neuropeptide involved in reproductive partnerships and associated with recognition and social memory. However, Oxytocin is not limited to reproductive relationships, and stimulates reinforcement for many positive interpersonal interactions and relationships. Application of OT increases prosocial decisions, being attentive to others, and increased trust and generosity. In addition to Oxytocin, the opioid β-endorphin plays a crucial role in interpersonal relationships through its influence on reward processes and social behavior. Researchers suggest that while OT facilitates social interaction, β-endorphin is essential for the creation and maintenance of social bonds. Serotonin and dopamine are also notable neuromodulators. Dopamine's effect on the formation of social memories and preference is a part of the ventral tegmental area. In addition, researchers believe serotonin modulates how we perceive and respond to social information (Interpersonal Chemistry in Friendships and Romantic Relationships). Behavioral data shows a correlation between pathways of sex drives and love within the brain. In fact, sexual attraction and attachment work together in the neuroendocrine system to influence preference of mating partner (Toward a Comprehensive Theory of Love: The Quadruple Theory [Attraction, Connection, Trust, Respect]). Romantic and platonic relationships share many chemical similarities because the reward systems in our brains find many of the same benefits in both of these relationships. Love can be synonymous in romantic and platonic relationships, which is expressed through these chemical reactions.

DUALITY OF MODERN MARRIAGE

Gabriel M. Walz of The Saint Paul Seminary School of Divinity says spousal friendship prevents the disintegration of the spousal relationship and strengthens it into an enduring relationship. The commitment of marriage is protected by the open communication of love of a spousal friendship because the vulnerability needed for growth can be achieved through a balance by acceptance of the other which removes the fear of rejection; however, relationships lacking comparable commitment dissolve easier. In a biological sense, platonic love through friendships, is seen as a benefit and can help one obtain better resources, like a symbiotic relationship. However, romantic love is much more rewarding in a biological sense, as it tends to allow the two members to procreate. This being said, no romantic

love is necessary to procreate, nor is any love. Romantic love is a complex concept that people struggle to define universally, as everyone experiences it differently. Sociologically, romantic love in relationships is a driving force in marriage, which can be referred to as a social construct. Depression and loneliness can lead people to live shorter lives and studies show that married men live longer than unmarried men. This could be due to many factors, including companionship, stability, and having someone who takes care of you. These aspects of relationships are not limited to romantic relationships, however most lifelong friends do not live together, and most married couples do (Toward a Comprehensive Theory of Love: The Quadruple Theory [Attraction, Connection, Trust, Respect]). This study by Elisabeth Camirand and François Poulin at the University of Quebec found that, when observed synchronously, conflict and intimacy in platonic and romantic relationships have different effects on the psychological well-being during emerging adulthood. They state that emerging adults who suffer from depression are more influenced by conflict in their intimate relationships, and the depressive symptoms hinder the quality of these relationships. Concurrently, the study exemplifies the protective role of intimacy with one's best-friend on loneliness and self-esteem during emerging adulthood. Although emerging adulthood is commonly defined by its strong association with romantic relationships, during this period, platonic relationships have a prominent role as well. Therefore, the study illustrates the simultaneous importance of platonic and romantic interpersonal relationships in emerging adulthood, emphasizing neither is more significant than the other.

BEHAVIORAL CHARACTERISTICS

Analyzing behavior is one of the many research methods used by psychologists. While I was unable to observe and analyze behavior, I was able to conduct a survey among my community asking about behavior in relationships. Although claiming to behave certain ways is different from actually behaving in those ways, I thought this the most efficient and effective way to gather data for a small research project. I felt unsatisfied with the amount of data and content I was able to find while researching shared behaviors in romantic and platonic relationships, so I conducted my own research by creating a survey with my foundation instructor, Vincent Favilla. I then distributed it via my classes and social media. I was able to obtain 24 responses to my questionnaire. I then collected the data I received and grouped it by relationship type. I found many trends. I saw that in five out of the nine behaviors mentioned in the survey, responses to both types of relationships answered the same frequency within a 5% margin. Meaning, about the same amount of people do these 5 behaviors at the same frequency in both romantic and platonic relationships. This shows the clear connection between behavior in both types of interpersonal relationships, as not only were these behaviors shared, but so were the frequencies of them.

Social Differences

As aforementioned, platonic and romantic relationships are not the same in totality. In fact, if they were, there would be less of an emphasis on dating prior to marriage. Socially, these two concepts are entirely different and should be treated as such. A key social difference between romantic and platonic relationships is exclusivity. Typically, in romantic relationships, each partner is only seeing the other and not engaging in other romantic endeavors; whereas, in platonic relationships, it is generally assumed each member has other friends. Platonic relationships lack this level of exclusivity. However, this is not substantial evidence for the absolute separation of platonic and romantic relationships as polyamorous relationships are becoming more common. Polyamorous relationships are relationships that involve emotion, intimacy and sex with multiple partners. Although less common than monogamous relationships, polyamorousness debunks the need for exclusivity in a romantic relationship. Another key difference socially are the expectations within each relationship. In romantic relationships, people are expected to provide much higher levels of admiration, attention and time to their partners than in platonic relationships (3 Key Differences Between Intimate Friendships and Romantic Relationships). Although varying between every relationship, couples in romantic relationships typically spend more time together than friends in platonic relationships. This may be because they live together and are physically present more often, or simply because the relationship requires more upkeep.

HOMOSEXUAL PERSONAL EXPERIENCES

As I was exploring my topic for research initially, I hesitated making the assertion these two types of interpersonal relationships are homogeneous psychologically, simply because of the innate differences they have socially. However, the claim fascinated me and was quite debatable and untouched. The notion that these two relationships are generally the same psychologically is not a common thought, simply because this is not something the average person struggles with in their life. However, many members of the LBTQ community have had similar experiences. For example, in one of the quotes from an article I found,"Kazuo" states they have been in love with their

best friend since three months into their four year relationship. Their relationship is intimate emotionally and physically, as Kazuo and their friend started having sex when they lived together. However, Kazuo noted the toll this aspect of their friendship had taken on them, as their friend does not share the same kind of love for them (13 Queer People Share What Happened When They Fell In Love With Their Best Friend). This is a phenomenon typically referred to as "friends with benefits", in which two friends engage in sexual behaviors with each other without dating, sometimes even without romantic attraction. Many of the other personal anecdotes share their apprehension to let the other know how they felt, as they did not want to jeopardize the relationship. However, speaking from someone who has had friends to lovers fail and succeed, it is always worth it. Some of the stories shared in the article describe partnerships that have a strong platonic foundation and grew to become a romantic relationship. As I explained through friendship in marriage, this foundation increases the strength and vulnerability of relationships, leading them to last longer.

CONCLUSION

However strange and puzzling this assertion may be, the psychology of romantic and platonic relationships share undeniable similarities. Since the chemicals released during each relationship targets the reward systems in our brains, many of the same chemical processes occur. Through a strong foundation of friendship, romantic relationships can be stronger and more vulnerable, leading to increased longevity.w Tangible behavioral data I personally conducted proved that each relationship type performed five behaviors at approximately the same frequency. Homosexual experiences concur my findings as these individuals fell in love with their best friends. However one may love, it shall always be something worth exploring.

WORKS CITED

Angelini, Jillian. "13 Queer People Share What Happened When They Fell In Love With Their Best Friend." Women's Health, 12 Sept. 2023.

Camirand, Elisabeth, and François Poulin. "Links between Best Friendship, Romantic Relationship, and Psychological Well-Being in Emerging Adulthood." 2022.

Campbell, Kelly, et al. "Interpersonal Chemistry in Friendships and Romantic Relationships." The Social Science Journal, California State University, San Bernardino.

Cramer, Duncan, and Marie Donachie. "Psychological Health and Change in Closeness in Platonic and Romantic Relationships." The Journal of Social Psychology, vol. 139, no. 6, 1999, pp. 762-767.

Crossman, Ashley. "The Definition of Marriage in Sociology." ThoughtCo, 30 Jan. 2020, www.thoughtco.com/marriage-3026396.

Gonzaga, Gian C., et al. "Love and the Commitment Problem in Romantic Relations and Friendship." Journal of Personality and Social Psychology, vol. 81, no. 2, 2001, pp. 247-262.

Guinsburg, Philip F. An Investigation of the Components of Platonic and Romantic Heterosexual Relationships.

Pinto, Rodger P., and James G. Hollandsworth Jr. "A Measure of Possessiveness in Intimate Relationships." Journal of Social and Clinical Psychology, vol. 2, no. 3, 1984, pp. 273-279.

Poitevien, Jessica. "3 Key Differences Between Intimate Friendships and Romantic Relationships." The Skimm, 29 Aug. 2024.

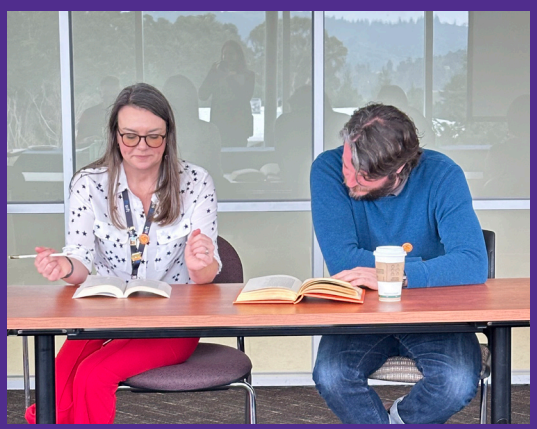
Rubin, Isaac Michael. The Social Psychology of Romantic Love. University of Michigan, 1969.

Sibley, Chris G., and James H. Liu. "Working Models of Romantic Attachment and the Subjective Quality of Social Interactions Across Relational Contexts." Personal Relationships, 2006.

PARADISE LOST

The CSM English Department kicked off the start of the spring semester by hosting the very first marathon reading of John Milton's "Paradise Lost!" The fateful quest of reading the entire epic in one sitting commenced at 8:00 am and completed by 6:22 pm that evening. Staff, students, and community members joined in on this enriching event that also hosted mini creative writing, poetry, and craft workshops. Don't miss the next reading, Spring 2027!

CSM COLLEGE OF SAN MATEO
English Department



WALKOUT

Photography by Itzel Quirarte & the Skyline view

Photography by John Tumalo
@framebysayn

01/30/26


GET PUBLISHED!
Illustration
Poetry
Creative Non-Fiction
Short Stories
Humanities &
STEM Essays
Digital Photography
Submissions open to all SMCCD students
https://labyrinth.submittable.com/submit