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Untangling the Intangible: The Folds of β-amyloid

The intersection of art and science is an ambiguous, yet fertile space that holds endless potential for creative exploration. Of the infinite number of biological topics that exist on every imaginable physical scale, there also exists an analytical and interpretive gradient, ranging from factual science to imaginative and emotional art. Finding the interesting points along this theoretical spectrum is one of the greatest challenges that I have realized throughout the course of my honors thesis. My journey has followed a pathway generating pieces that range dramatically in scientific, emotional, and visual content, and I have experimented with new techniques and media at every step. I have been challenged by both content and process, growing immensely in my approach to art-making throughout the course of this thesis. Here, I trace my journey and explain my most intensive artistic endeavor to date.

The starting point of my process was an interest in artistic microscopy - microscopy for the sake of an interesting image and not solely for gathering information. I browsed online galleries of beautiful images generated of weird and wonderful creatures, tissues illuminated by colorful fluorescence, and networks of neurons creating chaotic webs. The visual appeal of the images intrigued me, and I found myself desiring to know more about the subject matter. I wanted to know the story behind the bugs and diatoms illuminated on slides or beamed with electrons. Motivated by this fascination, I began some early experiments during my junior year in attempting to present model organisms in unconventional ways using an electron scanning microscope, which was both rewarding and incredibly frustrating. I found that using a microscope for photography has unexpected challenges, depending on what material is being imaged. Instead of using the rules and behavior of light to form images, the photographer uses electrons, which are directly influenced by what they are imaging. Despite the knowledge that this process could be particularly finicky, I still felt drawn to the potential in using this scientific tool to make art.

At the same time, I was inspired by what I was learning in my biology classes: patterns in evolution and the universal genetic code that characterizes every living organism. I felt that this code was fundamentally important, and I knew that I wanted to utilize it as the backbone of my pieces. This genetic code is essentially a process by which four chemical components (nucleotides) arranged in strings of DNA direct the production of thousands of completely different proteins. In science classes we all learned the clichéd phrase, 'proteins are the building blocks of life,' but really, they are even more than that. Proteins are the builders and the building blocks alike, and they are also the demolition crew. The idea that proteins can be destructive and harmful as vehicles of disease was something that I found particularly compelling as potential subject matter. I knew that whatever protein I chose to depict needed to be significant and meaningful to an audience beyond the scientific community, despite my integration of a very technical subject-matter, and disease was one particularly relatable topic.

Upon reflection, this process of identifying my subject matter was similar to the way in which one might ask a scientific question for experimentation. In all research, there is always a need to elucidate the significance and broader applications of a study, particularly in how they relate to humanity and our understanding of our environment. With this in mind, I chose to use the protein β-amyloid (Beta-amyloid) for its responsibility for forming the destructive neural plaques that cause Alzheimer's disease. I began a more intensive project of researching and reading scientific papers to learn more about the biological basis of the protein, investigating β -amyloid from its biochemistry to the social impacts of Alzheimer's disease.

From the huge amount of information gleaned from research, I began by replicating the code of amino acids. Unsure of how I wanted to depict this in a way that communicated both scientific and artistic concepts to a broad audience, I initially relied on the amino acid code to dictate my decisions. At this point in the fall semester, I was also taking a class entitled "Art Since 1960", and having learned about the prescribed art-making decisions of artists such as Sol LeWitt (most notably in his wall drawings), I thought that I could also pre-establish a code and set of rules that would both form visual properties of the protein and the mechanical folding process. I had ideas about making individual amino acids whose

colors represented their polarities (an important property in folding), whose sizes were all proportional, and whose folding sequences followed a known pattern of steps. The final piece would be dictated by these prescribed decisions and initial code, just as is the case in nature. At first I thought this was a wonderful idea – I could rely on research and scientific fact to interpret my creative sculptural shaping of the amino acids, and the research would support the final product, whatever final form it might assume. In this case, it was not necessarily the final sculpture that mattered as much as the process by which it was composed. I diligently began working, spinning colored threads on carefully-shaped wire armatures representing individual amino acids. My product (Figure 1.) was certainly interesting to look at, but I soon realized that I had traded much of the 'science' without gaining the artistic strength I had intended. I found that the most interesting aspect of my sculpture was actually in its photographic potential and interesting lighting effects.

Figure 1. Wire sculpture of β-amyloid. Colored thread and wire, 10' x 3'.

Realizing that the hard science references may distance me from my audience, I began to move away from a more rigid scientific world and delved into an exploration of how my sculpture interacted with light. I experimented with cast shadows and projected movement, bringing in the new medium of video to my explorations as a reference to light microscopy (Figure 2). I was particularly excited about using video to depict the process of protein folding in β-amyloid, because the process of misfolding is a major cause of proliferation and accumulation in the form of brain-damaging plaques. These plaques envelop neurons in the brain, preventing signaling and causing

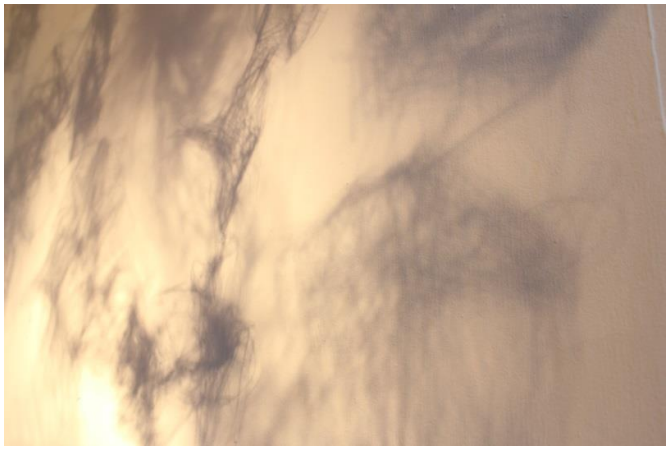

Figure 2. Still from a video of shadow movement in the β-amyloid sculpture.

them to die. This process is a particularly fascinating example of the destructive nature of proteins on both a microscopic and macroscopic scale. Finding the steps that led to this was one of my key questions, and I set about trying to gather research papers to find the answers. On one field trip with my honors thesis committee member Dr. Goldstein, I met with Dr. Kevin Slep, a professor in the Biology Department who uses protein imaging and crystallography in his research. In my conversation with him, I tried to ask how β-amyloid is known to fold and misfold, and he carefully explained that protein folding is really one of the great challenges to scientists. Proteins find their conformations in a matter of microseconds, and it is almost impossible to parse apart these microseconds to understand what actually happens. In that split-second moment, scientists can only generate a landscape of probabilities of protein conformations and folds, but the exact process is unknown and highly-dependent on a protein's chemical environment. Although I did not realize it at the time, I think this was my aha! moment. "So I could theoretically fold a protein however I might imagine?" I asked; to which he agreed. This turning point in the project signified a transition from my reliance on scientific data to an exploitation and exploration of the limits of that data. Suddenly there were far more options and directions that my project could take. I started asking more questions, such as, "How can I more creatively represent each individual amino acid?"; "What is the rhythm of a protein fold?"; and "How can a protein's representation be metaphoric of its function?"

I started to focus on answering these questions with an artistic interpretation in mind, instead of a scientific basis. I began by 'documenting' my imaginary process of β -amyloid folding using stop-motion photography, concentrating more on a rhythm of movement that would characterize a cyclical pattern of folding and unfolding. I created another sculpture of β-amyloid using white plastic bags melted to 42 wire frames corresponding to each amino acid in the chain (Figure 3). Although I replicated the true sequence and

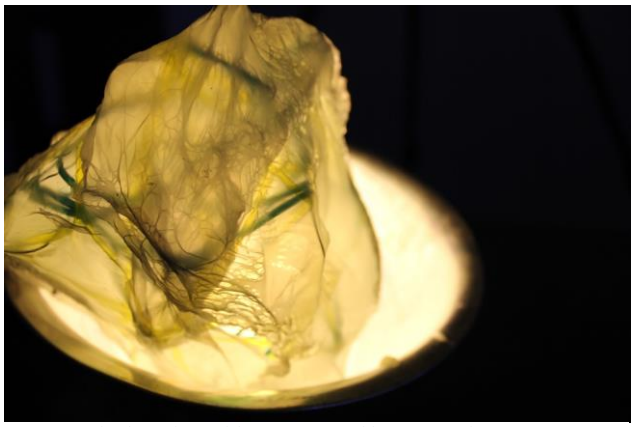

Figure 3. Single amino acid component of larger protein structure. 7" x 6" x10".

approximate scale of the amino acids with each frame, I chose not to complicate the sculpture with individual colors and designation of other physical properties, predicting that these elements might hinder the clarity of a stop motion specifically created to demonstrate an imaginative folding process. The sculpture itself measured approximately 30ft long when outstretched, appearing a little bizarre, and having surprisingly visceral properties. Depending on the lighting, the protein either appeared as a solid and twisted chain of weird and wonderful vertebrae (Figures 4 and 5), or it evoked a string of tenuous membranes that stretched and bulged, suffocating the surrounding space (Figure 6). I felt compelled to photograph the sculpture, finding these textures and forms to be metaphoric of the nature and physiological impact of β-amyloid on neurons. Zooming in on details of the sculpture itself revealed ideas and imaginative imagery of a zoomed-out perspective. The folds of plastic itself appear as amassed and decaying body tissue containing inner layers and deep gashes of missing material—another representation of the destructive effects of this particular protein. I entitled this series of photographs *Neural Melt* to reference the plastic-melting process by which the sculpture was made, and to create a broader connection to the gradual degenerative effects of Alzheimer's disease.

Figure 4. Original image from stop-motion photographs.

Figure 5. β-amyloid sculpture. Plastic bags and wire. 12' x 3' x 2'.

Making this inward exploration into the sculpture was a microscopic investigation of a larger stop-motion process. After numerous trials and experimentation with lighting, inversion, and techniques in making myself invisible as the manipulator of my sculpture, I managed to generate a sequence of approximately 800 photographs depicting an imagined unfolding. With video manipulation I


Figure 6. β-amyloid sculpture photography

experimented with patterns and speed of movement, attempting to emphasize both the complexity and rapidity of folding. I began to see and explore rhythms and repetition, playing with tensions in folding and timing, composing a story as the protein folded and unfolded continuously. I particularly enjoyed the visual effect I generated when these images were recast with lighting values in a negative form (Figures 7 and 8); to me they appear to exist in an ambiguous world with no sense of scale, a feature that is often conveyed by scientific diagrams of the microscopic world. The unusual lighting effects are distinctly reminiscent of electron micrographs, whose values and textures are determined exclusively by surface quality and texture. Despite the planning and intent I had while creating the shots, the final video product was nothing I could have predicted. The stop-motion animation, entitled *Within a Fold,* evoked a surprisingly playful tone that was completely unexpected, and which intrigued anyone I showed the video to. Immediately viewers asked: "What is that?!" in a very curious tone; which I didn't initially view as a positive reception. Indeed, the piece itself is unusual, yet oddly mesmerizing. A rhythm emerges that engages and draws the viewer in, regardless of whether he or she is an artist, scientist, or neither. Rapid and jarring undulations and transitions are offset by smooth and gradual movements, offering varying temporal textures in a world that could exist on any scale. The moving object could be as microscopic as a protein, or as large as a bizarre creature that


Figure 7. Still image from stop-motion video.

contracts and unfurls endlessly. The sequence begins with a slow and gradual transition in conformations, rapidly accelerating to a chaotic moving tangle representative of an actual folding process. My ideas in manipulating the rate of folding were based on my understanding of the proliferation of β-amyloid misfolding in the brain. Such misfolding patterns of proteins can often cause other proteins to misfold (these proteins are often referred to biologically as prions), creating an exponential increase in the rate of protein accumulation.

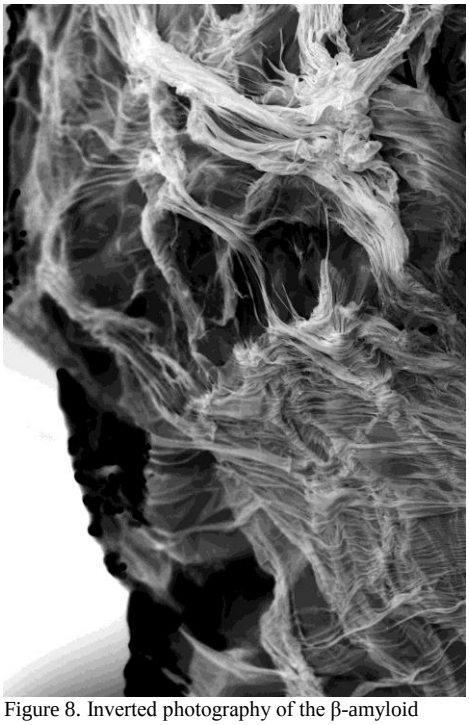

Figure 8. Inverted photography of the β-amyloid sculpture.

Knowing that my subject matter is typically smaller than a nanometer in size, I also wanted to incorporate a direct reference to microscopy. However, I again encountered limitations of the scientific world. Individual β-amyloid monomers are too small to image on an electron scanning microscope (EM), and their amino acids are even smaller. During this time that I was contemplating how to incorporate microscopy into my project, I had recently been on a field trip to the studio of a local letterpress artist Brian Allen, as part of my letterpress class. Shown a tiny piece of lead type that was 4pt, I immediately began to wonder what the embossed character would look like under the EM. Furthermore, I was acutely aware of the potential of letterpress to convey the practice of representing amino acid sequences by their 3-letter names. I became very excited about the prospect of connecting letterpress to microscopy and proteins, and I particularly liked the idea that I could link two very specialized techniques: a very old and highly-manual practice and a relatively new and computer-based technology. I used a

Figure 9. Compilation of 9 essential amino acids, imaged using electron microscopy of letterpress printed paper.

Vandercook press to print 8pt Eve font on Rives BFK in order to create an embossed effect that I knew the microscope could detect. I set and printed type for all 20 amino acids, imaging them individually in the microscope, and attempting to highlight both the texture of the paper and physical imprint of the letters (Figure 9). Using the three-letter code to represent an invisible amino acid using traditional techniques, while utilizing a scientific device to effectively collect this information, seemed to be an appropriate example of the ability of artistic and scientific tools to create an unusual and interesting image. My arrangement of the amino acids in a horizontal sequence on clear Plexiglass also emphasized a connection between language and code, particularly by establishing a cue for reading the specific amino acid code from left to right as though it were a long sentence. Printing the amino acids on transparent paper also enabled me to reference light microscopy and microscope slides. The piece is named *Slide Sequence: β-amyloid* to reference the specificity of the code, the connection to microscopy, and to provide potential exploration in other proteins by re-using the digital microscopic photographs.

After generating my microscopic images, I felt that I had a solid foundation of raw material from which I could compose a more comprehensive exhibition of alternative methods in understanding β-amyloid. My next problem was in bringing these elements together cohesively and in a manner that would be accessible, interesting, and resonant with both a scientific and artistically-inclined audience. My first idea was to create a scientific paper based on new explorations and discoveries of the protein, using my artwork as figures in the paper. However, this detracted from the artworks themselves, as they were forced to conform to a single format and reading of the paper. The images would exist only in the context of the paper, and not beyond it, limiting my ability to reach a wider and 'non-scientific' audience. I then explored the idea of using three pieces to represent 'alternative structures' of the protein, which would theoretically exist in dimensions unnamed by scientific convention, and which would cover a range of emotional reactions. Proteins are generally understood to have four main structures defining different spatial dimensions: their amino acid sequence (primary structure), preliminary basic folding patterns (secondary structure), the full three-dimensional peptide (tertiary structure), and the interaction and bonding of the peptides to form the protein (quaternary structure). I envisioned that I could artistically

depict structures that connected primary to secondary, secondary to tertiary, and tertiary to a broader, more human and physiological level with each of my pieces.

To convey a more emotional aspect of the implications of the protein with another piece, I returned to my original thoughts surrounding my selection of β-amyloid itself. My first two undergraduate years were filled with pre-med classes and volunteer work in a local nursing home. It was here that I first witnessed the late stages of Alzheimer's disease, and I was exposed to the reality that this same degeneration in elderly patients could easily happen to my own family members. At the time that I was volunteering, I wrote narratives about my experiences and encounters with the patients, acutely aware that they all were once perfectly healthy and capable people, with their own lives and the lives of their family members entirely upended by a disease. The fact that the accumulation of misfolded proteins could be the reason for this provided a clinical and unemotional explanation for an outcome that is incredibly charged with emotion. Knowing this, and considering the fact that Alzheimer's is becoming an increasingly prevalent disease, I felt that this aspect of the project may be especially relatable from a variety of audience perspectives. I considered visually integrating this serious and implied consequence of β-amyloid into the final project, as an exploration of emotional scale in presenting the protein.

Drawing from my own narrative writings and from material sourced from interviews with Alzheimer's patients describing their experiences, I began to experiment by setting the same type I used to generate the microscopic images, with the thought that I could overlay translucent prints of my sculpture photography. Unfortunately, this did not produce a satisfactory result in the context of my other work, as I feared that I had only managed to complicate my concept to the point where it was both emotionally and visually confusing. The grave tone set by the reality of the disease jarred with the sterility of the microscopic protein code and the visually-interesting and playful stop-motion sculpture, and I found that simply mirroring materials and typeface did not make the project unified. After beginning to experiment with display techniques and settings, I soon realized that my 'alternative structures' concept was very obscure. I had perhaps found a way to bind my physical pieces together under a single idea, but I had not found a way to successfully bind artistic and scientific ideas in a readable manner. The

connection to Alzheimer's was still important, but it could be communicated in a more simple and open-ended manner through its inclusion in an accompanying biological description of the work. By doing this, I could make the work function in multiple contexts: as something visually beautiful at a surface-level, but unexpectedly disturbing when accompanied by external content. Recalling the inquisitive reactions to the stop motion video, I reasoned that curiosity may lead viewers to re-examine the title or artist statement, just as I had relied on literature to answer my own questions about the process of protein folding.

My final presentation consists of my stop motion animation *Within a Fold* accompanied by my series of sculpture photographs entitled *Neural Melt*: a combination of two works that reference very technical scientific ideas at their core, but which are visually evocative and inviting to audiences of all backgrounds. During the process of deciding how to present my works, I came to the important realization that an artwork does not have to stay completely true to its originating ideas. My final pieces have no visual connection to the original protein code that I studied so intently that I actually memorized it, yet they are fundamentally borne out of a sequence and its abstract representation. By gradually letting go of my initial restrictions, I have been able to explore entirely new mediums and processes, generating work that represents a serious artistic journey.

Although much of my process relied on scientific sources, I frequently sought guidance and inspiration from artists working with similar ideas. Through my research of other artists whose work was relevant or inspirational to mine, I encountered a considerable amount of literature in relation to the bio art movement. Eduardo Kac, who coined the term and is known most famously for his *GFP Bunny*, is an artist whose work extensively incorporates biological subject-matter and mediums. He defines Bio Art as having one or more of the following approaches: "(1) The coaching of bio materials into specific inert shapes or behaviors; (2) the unusual or subversive use of biotech tools and processes; (3) the invention or transformation of living organisms with or without social or environmental integration" (Kac 18). Other definitions of bio art include a broader scope that uses scientific imagery or expounds upon a question, controversy, or missing element in biological research (Costa and Kavita 110). By Kac's definition, my

work is not bio art because it does not use living matter, even though it relies on laboratory research and imaging. However, with a broader definition in mind, my work is also heavily based on making art that addresses questions and unexplored elements in biological research.

One work by Eduardo Kac that directly addresses the biology of proteins is *Genesis,* a synthetic protein generated by replacing the first letters of the Biblical text with their corresponding amino acids, the result being a nonfunctioning and completely artificial protein. Kac's work is novel, and it brings about interesting thoughts about the significance of an arbitrary human-designated code used to represent and understand biological elements. I also found this representational system very interesting, primarily in its limitations of representation. The code itself generates a pattern which can serve as the blueprint for any aesthetic method used to represent its physicality, whether that is letter-pressed paper or melted plastic. Kac's ideas are particularly relevant to the ideas I considered at the inception of my project: strict and careful attention to the specific code, and a reliance on an arbitrary coding system to dictate artistic decisions.

Marta de Menezes's work is similarly entwined in science and art: much of her work requires the use of advanced biological techniques and lab work. Fascinated by the potential of biology to provide new avenues of creativity, Menezes also emphasizes that the bio art movement is increasingly based in a laboratory, requiring collaboration with scientists and training in techniques. My project similarly required collaboration with Chapel Hill Analytical and Nanofabrication Laboratory (CHANL) in using the electron microscope, and I gained a great appreciation for the experience and expertise of other scientists. Menezes stresses that the conversion of a studio to a laboratory is challenging to artists, who often have no significant background in the biological sciences, and that 'scientific communications are often unintelligible to outsiders to the field' (Menezes 218). This, too was something that I had gained to appreciate in my research, and my earlier idea of tying together my own pieces as figures in a scientific paper were borne out of this observation. Proteins themselves provide an exciting topic for bio artists, particularly for those who hope to explore genetics on a different level from DNA sequences. Menezes, who synthesized her own protein based on the letters in her name (*Proteic Portrait)*, observes: "Proteins

are frequently as beautiful as contemporary sculptures. Exploring a database of protein structures using software and hardware allowing three-dimensional visualization is like exploring an art gallery" (Menezes 221). Unlike Kac and Menezes, I chose to explore the properties of a biologically-significant protein rather than generating my own based on an arbitrary letter-coding from a significant text. Instead of manipulating the amino acid sequence itself, I took creative license in reconstructing its folding pattern, imagining the process as both chaotic and dance-like.

I have also been particularly interested in the work of Brandon Ballengée, a scientist and artist who focuses on using art as a medium for communicating scientific research, and vice versa. His work is largely based on ideas surrounding environmental stewardship, but like many successful scientists and artists, he poses his questions on a range of physical and conceptual scales. He explains in his artist statement that "all of [my works] try to re-examine the context of the art object from a static form (implying rationality and control) into a more organic structure reflecting the inherent chaos found within evolutionary processes, biological systems and nature herself" (Ballengee). This idea of inherent chaos is something that I slowly uncovered throughout the course of my honors thesis. While all life may be fundamentally founded on a simple universal code, the language that it creates is far more chaotic and random than can ever be fully understood. Ascending just two levels in the hierarchy of protein complexity yields an intricate folding process that is impossible to scientifically delineate and which defies the human inclination to resolve its mysteries. Like Ballengée, I find this inner chaos and the ensuing consequences to hold endless potential for art making.

Beyond the bio art movement, other artists and influences have stimulated my ideas. One of my favorite pieces is a short film by Ray and Charles Eames entitled *Powers of Ten*, in which the viewer soars through layers of magnification of a picnic scene in Chicago and zooms to the very limits of space. The idea is that each frame presents a 10x zoom in or out of the previous frame, providing a beautifully mathematical perspective of the insignificance of the human scale. Humans constantly try to map themselves in the context of time and generations (family trees) and geography (globes, google maps, novel wall-maps on museums showing visitors' hometowns), but they rarely have the chance to

conceptualize themselves in the context of scale. Humans view the world from a human-sized point of view, rarely considering the fact that they are composed of worlds upon worlds of complex processes occurring on every possible scale. Current endeavors in chemistry and physics are obsessed with this idea; the recent Large Hadron Collider experiments seek to understand the smallest scale possible—the composition of protons and neutrons themselves. Such ideas are incredibly difficult to grapple with without some reference to our human perception of the relative size of objects, and microscopy is a valuable tool in beginning to understand the layers of life of which we are composed. Microscopy provides a window into another world of a different scale, holding great potential for artistic exploration beyond the simple re-imaging of samples for studies. Regina Trindade, a bio artist, similarly appreciates the power of a tiny subject matter, writing that 'this interpretation of life at a molecular scale opens up a new level of intimacy with the body" (Trindade 285). I realized that referencing that intimacy and relevance to the human body was one goal that I needed to accomplish to create a finished piece that resonated with the audience.

Other influences stem greatly from my experiences as both a biology and studio art major. I have always been driven to understand scientific concepts visually, attempting to apply biological concepts as subjects of art, or attempting to understand scientific processes artistically. In either case, I am excited by the potential that each discipline has for contributing to the other. One influential reading along this theme was the work of German philosopher Arthur Koestler, who describes 'bisociation', or the intersection of different 'matrices of thought' to elicit creativity. His book *The Act of Creation*, describes the process of discovery and invention in humor, art, and science, encompassing topics ranging from the invention of tools to the poignancy of a joke. Throughout the process of creating my artwork, I continually assessed the relative contribution of artistic and scientific practices in forming a final product, and I found that achieving a readable balance was my main challenge to face.

While founded in scientific research, the project also exploits ambiguities in current biological knowledge, exploring the limitations of technology in conveying a full understanding of our biology. By integrating artistic disciplines such as letterpress, stop-motion photography, and sculpture, I bring a new

perspective to a topic that is of extreme biological importance, yet its function on a molecular level remains to be a mystery for many non-scientists. Issues such as the transparency of scientific communication, ubiquitous patterns in nature, and our human connection to our own chemistry are all elements that I have enjoyed exploring and would be eager to continue further.

These topics may all be subjects for my future artistic explorations. Considering my future as a scientist, I find the potential for art to contribute to scientific communication in unconventional ways to be particularly interesting, especially in its ability to evoke interest, critique science, and to elicit emotion from scientific discoveries. My work in this project begins to delve into these ideas, but further investigation remains, especially in relation to materials and technologies. My source of potential subject matter is endless; my challenge will be making decisions that will speak to a wide audience, bringing forth issues that are relevant beyond the scientific-research and art-world niches.

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