

PULMONAUT

LIA LARREA

PULMONAUT

Exploring the Intersection Between
Craftsmanship, Technology, and Fashion Design
Through the Science of Breathing
and the Art of Glass-blowing

LIA LARREA
Master in Fashion & Technology
2024
University of Arts Linz

DEGREE PROJECT
Master in Fashion & Technology

TITLE
PULMONAUT
Fashion Design //
Breathing Technology //
Scientific Glass-Blowing //

AUTHOR

Lia Larrea

SUPERVISOR

Karin Krapfenbauer

DATE
October 17th, 2024

PLACE
University of Arts Linz

ACKNOWLEDGEMENTS

First and foremost, I want to thank my mentor Günther Mausz, for sharing his invaluable years of expertise in scientific glass-blowing, along with his time, dedication, and collaboration throughout this journey. The skills I have gathered have made an insurmountable impact in my thinking process, inspiring me to create visions of dreams that have turned into a reality. Thank you for trusting my ideas and supporting me along the way!

I would like to thank my colleague Martin Schwab from the Creative Robotics department, for adding value to this project and consistently inspiring me to find creative solutions. His engineering experience, positive attitude, and kindness have been key in the realization of this project.

I am grateful to my professors Karin Krapfenbauer, Sander Hostee, Ute Ploier, Christiane Luible-Bär, Nina Wenhart, and Peter Holzinger for their advice and constructive criticism that have been instrumental to my growth throughout my studies.

I also wish to express my gratitude to my professors at the Swedish School of Textiles, Clemens Thornquist, Ulrik Larsen, Stefanie Malmgren de Oliveira, Marjan Kooroshnia, Erin Lewis, and Saina Koohnavard for being a valuable part of the learning process that has influenced the foundation of this project.

Special thanks to my team of creative collaborators for their care, feedback, and inspiration. To Gaia Cardamone, for her constant patience and support in elevating the video editing process. To Paul Kastler, for sharing his creativity and skills in sound design, adding a layer of multi-sensory experience to this vision. To Ariathney Coney, Xenia Schedlmayer, and Nina Braun, for their graceful performance during our fashion show. To Nadine Netzmann and Robin, for being part of the photography, and to Eduardo Moga for his expert feedback in this text. To Anna Deganello, Irina Graser, and Kseniia Starkova for sharing their energy for my final presentation.

My gratitude is also extended to Marta Rota, Valentin Weisinger, Giorgia Giuliani, and Lisa Gstöttner for supporting me during exhibitions, fittings, and presentations, and helping along the way with gracefulness and play. I thank the team at the Grand Garage for putting together a maker space where I have been able to connect with creative people and most importantly work with Günther Mausz. I thank my classmates at the Fashion Technology department for creating a supportive environment, as well as the team at the University of Arts Linz and the social media department for sharing our work.

Thank you to the Ars Electronica Center for choosing this project as part of their festival, and Innovation Hauptplatz for supporting our collaborative approach and motivating us to share our work.

CONTENTS

I.	ABSTRACT	4
II.	BACKGROUND	5
III.	HISTORY & MYSTERY	8
IV.	SCIENTIFIC CRAFTSMANSHIP	12
V.	DYING ART	15
VI.	STATE OF THE ART	18
VII.	RESEARCH METHODOLOGY	28
VIII.	EXPERIMENTAL METHODOLOGY	35
IX.	DESIGN RESULTS	71
X.	REFLECTION	108
XI.	CONTRIBUTION	113
XII.	REFERENCES	115

I would like to acknowledge my dear family and friends for their endless encouragement and support throughout these years. To my mother, Elaine Ibarra for showing me strength and resilience while flowing through life. To my brother, Adrian Larrea, and my sisters Fiorella and Camila Larrea, thank you for always being there for me. To my friends, Eileen Level, Karina Villca, and Mikeria Foreman, for showing the value of true friendships no matter the distance. To Damian Leszczynski, for his visionary creativity, inspiration, and endless love during the formation of these ideas and writing of this thesis.

Finally, I would like to send special thanks to my dear grandmother, Ligia Harnisth, and my dear Lupi Ibarra, for being the force behind this vision before I entered the Fashion & Technology program. They guided me through their final breath. .

I am honored to have such a wonderful and loving tribe of mentors, colleagues, friends, and family.

Thank you!

KEY WORDS:

// BREATHING TECHNOLOGY
// FASHION DESIGN
// SCIENTIFIC GLASS-BLOWING
// CRAFTSMANSHIP
// BREATHING INSTRUMENT
// SCULPTURAL FASHION
// FLEXIBLE GLASS
// CONSCIOUS FEELING
// CONSCIOUS MOVEMENT
// AWARENESS
// VISUAL HAPTICS

I. ABSTRACT

Pulmonaut creatively explores the intersection between craftsmanship, technology and design through the science of breathing and the art of glass-blowing in a sculptural fashion context. "As astronauts explore the depths of space, pulmonauts explore the depths of their breath" (Toth, J., 2023).

With the rise of digitalisation, this project aims to revive the dying art of scientific glass-blowing by co-creating with Günther Mausz, a Linz based Austrian craftsman who has mentored Lia with ancient glass-blowing methods. Hand-crafted wearable flexible glass instruments create a contemporary fashion collection that harnesses control and flexibility. Molten glass is blown, pulled and stretched to create organic curves and bubbles threaded through interlocking systems that generate an infinite connective puzzle. Glass embodies a symphony of surgical craftsmanship where movement and mindful breathing become frozen in time.

This approach aims to amplify
CRAFTSMANSHIP as an
ART of our FUTURE,
and **BREATHING** as a
TECHNOLOGY of our PRESENT.

II. BACKGROUND

We can survive three weeks without eating and three days without drinking, but for most of us we can only survive three minutes without breathing (Human: The World Within, 2021). We have experienced the impact of seclusion and the need for social interaction through lockdowns, travel bans, and the importance of feeling connected despite our background - whether cultural or social. This idea has inspired this project to search for a universal language of connection, where breathing has become the core of the design process.

The trauma of the pandemic has forever changed the way in which we live our daily lives, refocusing our attention on the importance of how we spend our time, how we move, how and where we work, and has also forced us to implement technology as a vital means of connection. However, despite the continuous advancement towards a virtual world, we still need to maintain our presence in our physical reality - not only through what we see, but through what we tangibly create. We've also gained awareness of the need to take care of our environment, and what it means to have clean air, whether indoors or outdoors. This has allowed us to become more mindful about the products we consume and how they affect our lifestyle.

Throughout history, breathing has been used as a tool to influence our bodies, our nervous system, our minds, and altogether our emotional states. This translates to the way in which we move, giving signs of our physical health while unlocking aspects of our well-being. Breathing and movement go hand in hand, defining how craftsmanship is a powerful messenger of the ideas that have shaped our ancient cultures and a guide towards our collective vision of the future.

Breathing and movement are essential parts of our daily lives. They are almost autonomous behaviors that seamlessly

connect and directly affect one another. The faster we walk, the faster we breathe, while the slower we walk, the slower we breathe. This can be seen in sports where athletes breathe faster the faster they run, whereas they breathe slower the slower they move.

In craftsmanship, the way in which an artisan manipulates a material is directly proportional to how they move, to how they breathe. For example, in scientific glass-blowing, the act of breathing is visualized instantaneously through glass, which could potentially give us an insight towards how a person moves, thinks and feels.

Meditation has become a widely accepted practice around the world, inspiring research and a new era of design that uses technology to enhance meditative states (Wu et al, 2014). Walking meditation is a common practice originating in Buddhism that has been used to enhance physical and mental health. Aside from the benefits of physical exercise, the non-physical range from feeling more "grounded, balanced, and serene", to developing a "different awareness of your surroundings, body, and thoughts" (Cronkleton, E., 2020). In the project "Multimedia-Assisted Breathwalk-Aware System", awareness is brought to the relationship between breathing and movement through the combination of technological systems and walking mediation to facilitate beginner meditators.

During walking meditation exercises, the principle of Breathwalk is used. The main idea is to "synchronize the footstep with appropriate breathing rhythm" through a sensor placed on a shoe that is linked to an app on a mobile device (Wu et al, 2014). This study showed that multimedia feedback, visual-auditory, could be used as a method to help meditator beginners to slow down the walking speed and "decrease incorrect footsteps, stepping retardation time, and

breathing retardation time” (Wu et. al, 2014). By applying this thinking process in craftsmanship, the possibility of creating new methods of design that refocus on our physical awareness alongside form and aesthetics to benefit our physical and emotional well-being becomes more viable.

The foundation of designing wearable flexible glass instruments in a sculptural fashion context develops the framing that what we wear could also create a multi-sensory experience. Wearing glass not only affects how a person moves and breathes, but also creates a connection between the audience since glass is a fragile material that must be treated with sensibility.

Shape and material are consistent factors that vary depending on the use. In sports, this is key in overall performance. For example, spikes are added to the frontal area of the shoe in order to add traction during sprints. In climbing, the toe is shaped to create a strong grip for surfaces at different angles, while in orthopedics for diabetic patients who are at “risk of forefoot ulceration”, rocker shoes are prescribed to reduce plantar pressure by increasing the angle of the frontal area of the shoe sole while reducing the height of the heel (Schie, Ulbrecht, & Cavanaugh, 2020). Alternately, for astronauts, the sole is made so that they could stay attached to the space ship through a clip heel, making them feel secure and grounded despite being in another world. All of these aesthetics impact how we move and how we relate to our surroundings.

Healthcare systems are evolving by implementing new technologies that impact the way in which patients are not only being treated, but what they are wearing while undergoing treatments. For example, in footwear, smart shoes are being used to monitor a patient’s health, which includes “coordinate tracker, step counter, calorie counter, as well as for biomedical information such as foot oxygen concentration (Hwang et. al, 2016). Another concept that is changing how we implement technology and research, is the new era of virtual reality which is also being used to

study mindful breathing (MB) patterns to relieve pain. Scientists are working on understanding the concept of pain being a multidimensional experience where the “brain integrates inputs from sensory-discriminative and cognitive-emotional systems as a central hub” (X.-S. et al, 2021). By using “augmented MB to an outside sensory experience via virtual reality breathing (VRB)” (X.-S. et al, 2021), researchers found that participants’ pain threshold increased during these sessions (X.-S. et al, 2021). Studies like this redefine how we perceive our reality and the importance of merging the non-physical with the physical in order to make the invisible visible.

With movement as a fundamental component in our daily lives, walking and the way in which we walk, is an essential aspect of how we breathe, and ultimately our health. In Japan, forest-bathing emerged in the 1980s as a “physiological and psychological exercise called shinrin-yoku”, where taking long walks in nature is the highlight of the experience (Fitzgerald, S 2021). It has become a common practice that brings a new sense of awareness and care for our world, which is an essential piece of cohabitation. We are currently living in the Anthropocene, which is described as the geological age in which “human activity started to have a significant impact on the planet’s climate and ecosystems” (National Geographic Society, 2022). Slowly, the need for change in our societies has become more evident with the pollution of our oceans, deforestation, and intensified natural disasters. As a result, we face an era where our own survival is threatened; by us. However, as designers, we have the ability and responsibility to choose based on how our present actions impact our future. In Metadesigning Designing in the Anthropocene, creating sustainable products is still important, but there is a larger incentive for us to implement “synergies that will induce regenerative lifestyles” (Dalladay-Simpson, J. (2022). This thinking process inspires the aesthetic development of new forms and aesthetics to bring forth our inherited inner technology alongside craftsmanship during a time of digitalization. As a result, our breath could be used as a tool not only for

survival but, but for artistic creation in connection with glass-blowing.

The fashion design field is one of endless possibilities, where dreams of the future can become ideas of the present. We see that our physical and emotional well-being are key components of our lifestyle and the relationship we hone with our environment. The wellness industry is expected to grow by 9.9% on average annually, to \$7.0 trillion in 2025, creating an opportunity to develop products that enhance our lifestyle, connect us to each other, our environment, and ourselves more deeply without the need for mass production (Statistics & Facts, 2023). This opens up the opportunity to merge fashionable wellness alongside craftsmanship to stimulate specific physical and mental states. Another interesting perspective is that although it is no secret that our bodies age and transform through time relation to our lifestyle (Aging changes in body shape: Medlineplus medical encyclopedia (no date) MedlinePlus), once we reach maturity, some clothing, footwear and accessories can be worn for countless years and can be passed down through generations. Therefore, creating sustainable, and generative wearables that induce mindful breathing, movement, and a generative lifestyle is at the core of this project. The structure of the glass instruments embody shapes that force us to balance, to lift, to push, to hold, to enhance our physical abilities through mindful breathing and movement in a contemporary fashion context.

The central focus of this investigative project is to uncover the connection between the unconscious act of breathing and the conscious process of glass blowing, positioning breath as an influential shaping tool and craftsmanship as an essential artistic practice. This thesis seeks to understand the technical and non-verbal language of ancient glass making techniques by analyzing the history behind this craft and the technology of breathing techniques embodied by artisans.

This method could trigger breathing patterns that could potentially enhance our mind and body connection. By

implementing modularity and flexibility, these wearable instruments become more than an accessory we move in, but one that we evolve with.

In order to co-creatively design, a layer of sculptural fashion adds dynamic elements by placing tradition and innovation as building blocks rather than opposing methods. This approach aims to amplify the creative process by expanding the artisan’s capabilities within design and bringing forward wearable art inspired by the exchange of breathing technology and the fluidity of molten glass.

III. HISTORY & MYSTERY

The history of glass opens a path filled with mysterious puzzles leading to questions about our ancient cultures and the development of artistic traditions. Glass, seemingly simple yet foundationally necessary, is used in our daily lives from the screens on our smartphones to windows, kitchenware, and more importantly for data transfer in fiber optics, plays an eminent role in our daily lives. However, "this material, born from fire, is shrouded in mystery" (Kostbarkeiten der Glaskunst, pg. 5). Glass has evolved with humanity throughout time, from the ancient civilizations of Mesopotamia to the skilled artisans of the Roman Empire. Despite its widespread use, "not only the circumstances of its invention are unknown, but also its internal structure" (Kostbarkeiten der Glaskunst, pg. 5) The historical duality and mysterious nature of glass inspires its timeless exploration and highlights the importance of its use in science, technology, and the arts.

According to historical accounts, as articulated by Pliny, the Roman historian, the discovery of glass is attributed to Phoenician sailors, approximately 4,000 years ago in Mesopotamia by chance. Reportedly, they constructed a cooking area using soda blocks on a sandy beach. After extinguishing the embers, they

discovered a remarkable transformation where the heat mixed with sand and other minerals melted into a surprising glassy form (Corning Museum of Glass (n.d), All About Glass, The Origins of Glassmaking). This event portrays the mystery related to the genesis of glass, and emphasizes the unpredictability of its creation that has led to questions that prevail to this day.

The exploration of the history of glass, as discussed in Invention in Early Glassblowing - The Road to Ennion with Bill Gudenrath | Behind the Glass Lecture, also unveils a beautiful journey through the evolution of this ancient medium. The lecture investigates different techniques between natural and man-made glass in both cold and hot working methods. Cold working techniques, such as carving and lapidary, involve shaping glass after it has cooled. This method displays the meticulous focus and dexterity needed to create intricate designs by artists of this craft.

The lecture investigates other hot working methods such as slumping and flame-working, which were also prevalent in ancient cultures. Slumping involves bending or shaping glass through controlled heating and cooling processes where sheets of glass



Cold Working - Carving



Cold Working - Carving



are melted into molds using gravity. Additionally, flame-working, a delicate process where artists manipulate glass using a torch, is a highly delicate and precise technique used to create intricate and detailed pieces. These methods underscore the versatility of glass as a medium and emphasize the rich historical context of glass making techniques over centuries and showcase the dynamic nature of this art form. "Invention in Early Glassblowing" brings light to the legacy of glass making, where craftsmanship and innovation grow together through techniques that have shaped the art of working with glass throughout the ages (Behind the Glass Lecture, 2015).

Working with glass has continued to evolve throughout history, not only through different methodologies using a variety of tools, but integrating the artisan's body in a remarkable way. The discovery that glass could be blown, was a significant technological leap that revolutionized the entire glass industry (Journal of Glass Studies: Volume XIX, 1977, p.9). This breakthrough transformed the manufacturing processes and opened new forms of artistic expression that highlight breathing not only as a shaping tool, but as a technology. This approach allowed artisans to shape and manipulate molten glass with a new movement and flexibility that was not possible with the use of traditional methods.

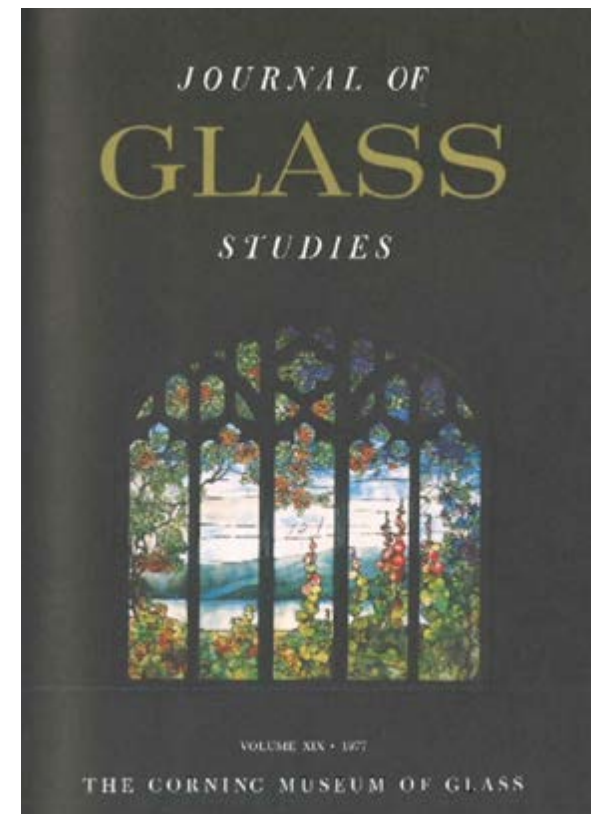
The act of breathing with awareness is a milestone that paved the way for dynamic glass-blowing techniques that have contributed to the transformation of this industry where technique and artistry blend.

Although there have been various technological advancements within the shaping and production of glass, research continues to show us that there is more to discover. In a study, "Structure of International Simple Glass and Properties of Passivating Layer Formed in Circumneutral pH Conditions", the importance of analyzing glass at its molecular level is emphasized as a foundational step. However, despite the efforts put forth in the study of this process in recent decades, the atomic structure of the International Simple Glass (ISG) remains unclear (Collin et al., 2018). This opens up opportunities to further investigate the history of glass as a medium for craftsmanship and scientific advancement.

Traveling back in time to Mesopotamia, glassmaking unveils a fascinating journey between history and mystery, where "ritual blended with technology". The Glassmakers Of Herat documentary from the Corning Museum of Glass sheds light on the intriguing glass-making preparation instructions that visualize the technical process while investigating a



Mold - Pouring Core Forming - "1,400 yrs. Of tech" Slumping Flame Working



sacred ritual. The recipe of glass-making, found in cuneiform tablets, described meticulous steps, such as searching for a favorable month, making sacrificial offerings, burning juniper incense, and pouring libations of honey and liquid butter, are highly questioned in science in our modern day. However, the profound ritualistic aspects embedded in the glassmaking process also include technical steps that emphasize the eminent coexistence of ceremonial traditions and technological expertise (Brill, R.H. and The Corning Museum of Glass, 1977).

The ancient recipe for glassmaking "is shrouded in mystical rituals", but it is noteworthy that the same basic ingredients are still used in contemporary glass production (Corning Museum of Glass, n.d). By combining ritualistic elements with technical procedures that are alive to this day, glassmaking is an ancient practice that could help us enhance more technological advancements and understand our human history.



IV. SCIENTIFIC CRAFTSMANSHIP

Glass-blowing exemplifies the fusion of technology and artistry, bridging scientific research with aesthetically pleasing forms where the known and the unknown meet. Lynn Poole's words in "The Johns Hopkins Science Review - The Master Glass Blower" describe the glass blower as a "master craftsman whose skill is one of the most delicate in any field in the entire world" (Poole, L. et al.,1951). Scientific glass-blowing requires extensive skills through precise techniques that embody mindful movement, breathing techniques, and cognitive thinking. The scientific instruments that they create are not only intricate, but precise to the one thousandth of an inch, ranging from laboratory glassware to lenses for telescopes and microscopes (Poole, L. et al.,1951). The material qualities of glass

also make it an invaluable medium for its transparency and malleability allow scientists to explore the unknown realms of the microscopic and telescopic worlds bringing forward discoveries that have propelled mankind.

Throughout the years, scientific glass-blowing has become a less common practice, however, it is an indispensable discipline within the scientific community. Research is an area with unpredictable experiments that make it impossible for commercial glass companies to anticipate the daily needs of scientists. As a result, universities recognize the necessity of employing a skilled and versatile scientific glass-blower, characterized as a "master craftsman", for they are given rough drawings that must be 25,000 of an inch precise (Poole, L. et al.,1951). Additionally, they must be able to translate scientists' visions into precise glass apparatus, further highlighting the importance of collaboration within different disciplines in order to advance research.



SCIENTIFIC GLASS-BLOWING PROCESS
John Lehman - Master Glass Blower 1951

V. DYING ART

Glass-blowing craftsmanship dates back to thousands of years of human history. Although it is still practiced today, the focus on its importance has decreased with the rise of digitalization. Manufacturing techniques employ molds and even robots in order to compensate for the market demand, however, as consumers become more aware of the environmental impact of these systems, the focus on handcrafted artifacts rises, making the revival of glass-blowing an exciting opportunity.

Scientific glass-blowing is a truly unique craft that takes years to master. Not only does it take physical endurance, but also mental strength - the resilience, patience, and thinking methods create new sets of challenges that not many endure. Borosilicate glass, used for its high resistance to thermal shock, gives the craftsman only about 10 working seconds to manipulate the glass. For this reason, the steps needed must be practiced and thought out meticulously for extended periods of time. Moreover, the foundational skills require continuous practice that vary from person to person, while glass itself can easily break even after all steps have been accomplished. Its beauty and mystery still invites admiration, but these challenges keep many at a distance from diving into learning how to work with glass. As Matt Rosen, director of the Low-Field Imaging Laboratory at the MGH Martinos Center for Biomedical Imaging, lamented, "Scientific glassblowers, like streetcar conductors and silent movie organists, are a vanishing breed" (Rosen, The scientific glassblower making one-of-a-kind equipment: 101 jobs that change the world (EP 17), 2021).

The tradition of glass in both art and science, has experienced a gradual decline over time. For example, in the United Kingdom, the heritage craft of glass eye making is currently classified as "critically endangered," with only two professionals practicing this intricate skill that takes years to master (Lewis, M., 2021). This brings us to question where the future of this craft lies, encouraging a collective effort to revitalize it as a vital part of our cultural heritage.

Glass as a material not only represents versatility, but it is valuable along diverse industries. For example, the creation of eye prosthetics is a particular blend of craftsmanship, artistry, and technology that is crucial to our collective history dating back to the early Egyptians who fashioned the first artificial glass eyes around 2613-2494 B.C. In 2006, an imperative discovery was made in Iran's Burnt City, where the world's oldest prosthetic eye was found embedded in the skeleton of a woman's skull (Prasad and RK, 2023). This event inspired researchers to recognize glass as a timeless material and its historical roots in human evolution. This ancient cyborg is a meaningful example of how glass prosthetics seamlessly integrate the body with technology, blending technical artistry with medical expertise.

Glass-blowing is a fascinating process at the intersection of scientific inquiry and artistic expression. The various applications of this material in technology, art and science, in combination with the physical and mental skills needed, force the artist to observe both outwardly and inwardly by focusing on the material itself while consciously manipulating with breath. In James Nestor's "Breath: The New Science of a Lost Art," Nestor investigates the profound impact of ancient breathing techniques that have been revived during recent years, and how they influence our well-being.

During the Enlightenment of the late 18th century, the transition from alchemy to chemistry was greatly influenced by glass as mentioned in "Laboratory Scientific Glassblowing: Advanced Techniques And Glassblowing's Place in History" by Paul Le Pinnet. Glass vessels became more commonly used for scientific research, making it possible to test more chemicals and approach more challenges than ever before. In 1774, Joseph Priestley conducted the "Common Air" experiment where glass vessels were used to demonstrate that common air is composed of different gasses and questioned the belief that air was a homogeneous substance (LePinnet, P., n.d). This ground-breaking discovery allowed scientists to visualize individual gasses and further analyze preconceived ideas about the world we live in.

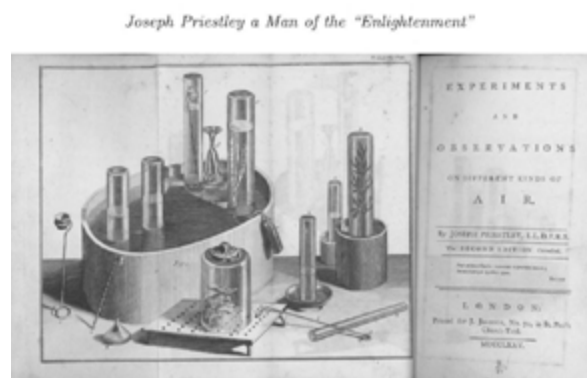
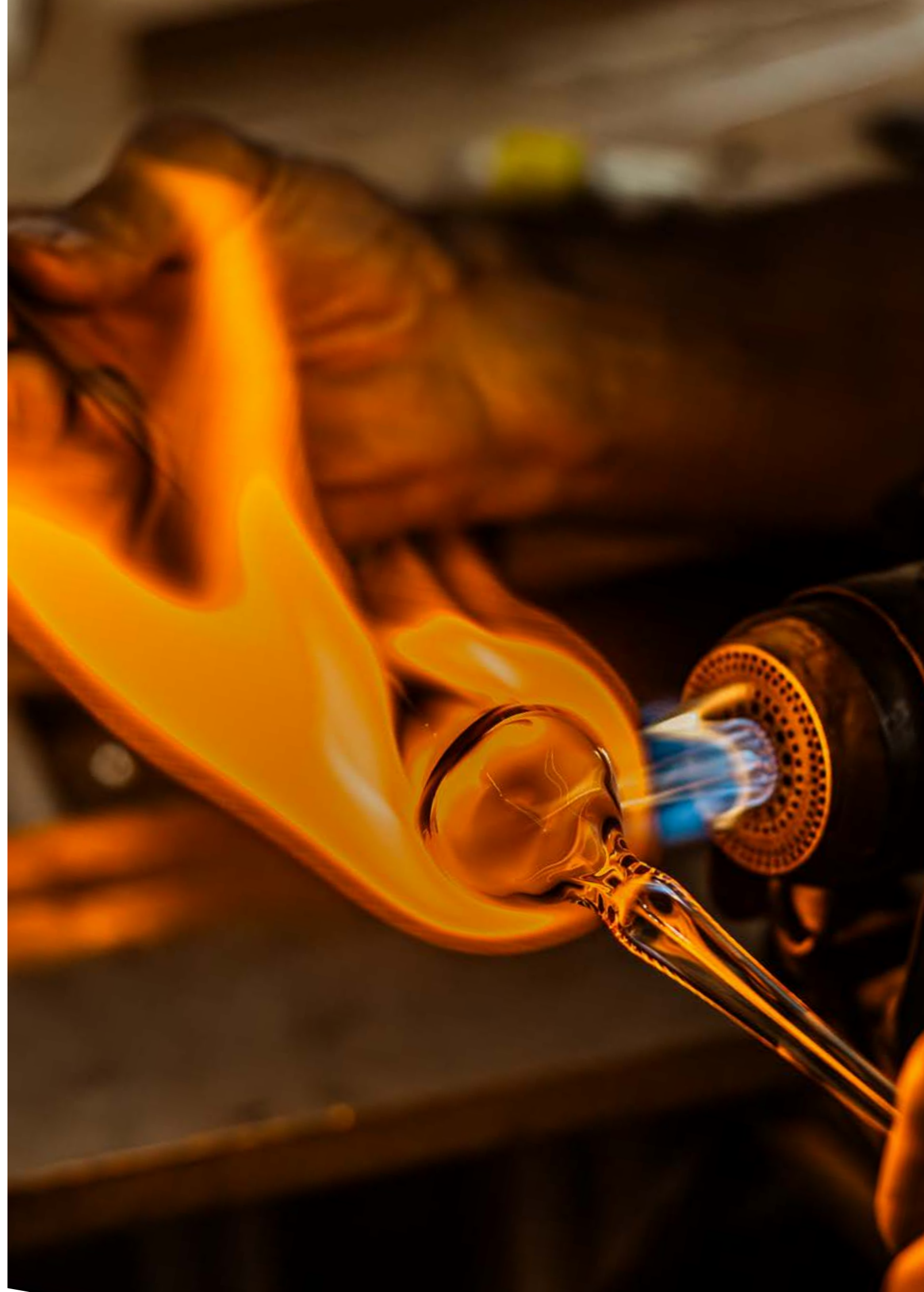


Figure 2. Common air experiment.

The history of glass in science has also led to significant medical advancements that have impacted healthcare practices and generations of children all around the world. The infant incubator by Stéphane Tarnier in 1880 was a pioneering device that changed the way premature or ill infants could be taken care of. It was designed with a thick glass lid to provide a controlled environment that effectively radiated heat and created a warm and protective space for up to four infants simultaneously. This innovation reduced infant mortality rate by half and demonstrated yet another example of glass' versatility and role revolutionizing medical care (Rebovich, 2017).



As a result, this research inspires the exploration of the relationship between ancient breathing techniques and glass-blowing methods. Nestor expands on how “breathing is the only system in the body that is both automatic and also under our control”, further recognizing how crafting glass is not only a technical artistic endeavor, but it also engages the mind and body in a holistic way (Nestor, p. 4). Understanding the transformative power of breathing as a technology, connecting both physical and non-physical aspects of artisans and glass, could potentially revive the dying art of glass-blowing. As Nestor highlights, “breathing can be used as a tool to shape our own health, to navigate our own minds, to reshape our own bodies”, and to question whether breathing can also be used as a tool to influence the societies of our futures, both by shaping the art we create and ourselves in the process (Nestor, p. 4).



VI. STATE OF THE ART

Throughout this research, the application of glass in fashion has evolved from exploring craftsmanship to understanding dynamic methods that have been applied in modern art. For centuries, glass working techniques have remained unchanged, challenging this medium as wearable. This thesis seeks to investigate different artistic expressions while analyzing the techniques that embody breath as a shaping tool, synthesizing tradition and modernity through contemporary fashion.

Bubble Dress | Iris Van Herpen, 2016

Iris Van Herpen, the Dutch designer known for intricate designs that merge technology and artistry, revealed the Bubble Dress in 2016.

This breathtaking design was made out of thousands of glass blown bubbles coated with transparent silicon to achieve flexibility, creating a “bioluminescent prism around the body” (Van Herpen, 2016). This dress showed a new dimension of the application of glass as a wearable medium.



Dimensionism Dress | Iris Van Herpen, 2021

Another creation by Van Herpen is the Dimensionism Dress in 2021, which was described as “closer to being a ghost than being a dress” (Machlich, H., 2022). This design evolved from a collaboration with glassblower Bernd Weinmayer who also used scientific glass-blowing methods to connect and shape glass-blown rods into a dress that appears to simulate the wings of a butterfly. In both designs, breath is a highly technical yet organic sculptural tool used to mold and transform glass into a collective structure. This approach challenged conventional fashion techniques by blurring the boundaries between the ancient art of glass-blowing and contemporary haute couture, while serving as a strong example of the power of collaboration between craftsman and designer.



**Coperni Glass Handbag
| Stephane Pelletier, 2023**

Glass has been more commonly used in fashion accessories, representing a strong use of color, shape, and innovation to create functional designs. The Coperni glass handbag by Stephane Pelletier, showcases the strength of merging traditional techniques in craftsmanship with functionality (Glass Blowing a Luxury Handbag With Master Craftsman | Every Step To Make | Vogue France, 2023). This design not only stands as a wearable accessory, but it also introduces the fragility of glass as a sculptural art form.



Glass Fashion | Laura Donefer, 1989

Glass is a strong medium that can be transformed into incredible shapes, however, it is not commonly wearable because of its structural qualities. In 1989, Laura Donefer, a Canadian-American artist, presented a wearable glass fashion collection at the Corning Museum, incorporating glass into haute couture. Donefer's work showcased the versatility of glass, and marked a pivotal moment in reimagining the possibilities of how glass could be applied in fashion as a form of artistic expression (If the Glass Fits, n.d.). More than twenty years later, we are still exploring this material throughout a variety of techniques that remain to be fully unraveled.



Telepathy | Laura Couto Rosado, 2012

Laura Couto Rosado explores the symbiosis between design, science, and technology. Her speculative design project, "Telepathy," was conceived during her Master's studies in 2012, and introduced a visionary approach to glass in fashion. Rosado's work consisted of a series of blown glass helmets that symbolized telepathic communication, making glass more than a wearable, but a part of the body. Her approach successfully blurred the boundaries between materiality and concept, envisioning a futuristic perspective on the intersection of glass and speculative design (Couto Rosado, L., 2012).

Steel Profile | GJS Bakker's, 1971

GJS Bakker, a Dutch jewelry and industrial-designer, created Steel Profile in 1971. This piece, although not directly made of glass, represents a paradigm shift in jewelry design; it is not an adornment, but rather becomes a part of the body.. Described as "not craftsmanship but sublimation of form," Bakker's conceptual design transformed traditional jewelry synthesizing the body in a transformative approach (den Besten, L., n.d.).



Lenticular | Naomi Filmer

Within jewelry design, Naomi Filmer's creations are distinctive for being perceived as wearable objects about the body rather than traditional jewelry. Her artistic process observes the body and highlights "ordinary parts of the body that we never really celebrate, but actually there is nothing ordinary about them at all" (Highlike.org, n.d.). By using glass, her work is able to isolate specific shapes while creating static movement. Filmer also recognizes breathing as an inspirational part of her working methods, while her approach challenges conventional jewelry norms through glass.



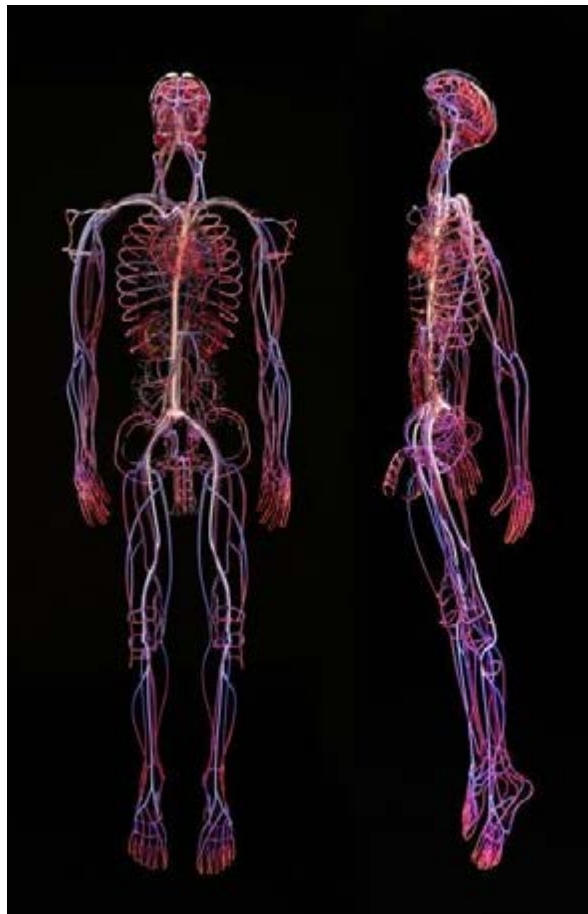
Supraorganism | Justine Emard, 2020

In the domain of sculptural and installation art, glass is a commonly used medium for it plays a transformative role redefining form and perception. *Supraorganism* by Justine Emard, is a glass installation that combines data gathered from a community of bees featuring robotic sculptures animated by artificial intelligence (Emard, J. 2020). This artistic approach visualizes the dynamic interplay between breath as a shaping tool and machine learning technology through the transparent essence of glass, giving tangible form to intangible concepts.



Inside | Bernd Weinmayer, 2022

Inside, a glass sculpture created by Bernd Weinmayer, the co-chairman of the Austrian master examination commission for scientific glass. This work embodies the technical precision of glass-blowing alongside artistic expression by blending sculptural art while manipulating light and shadow (Bernd Weinmayer, 2022). Breathing takes on a dual role as a physical shaping tool, but also symbolically representing the breath of life within the art piece.



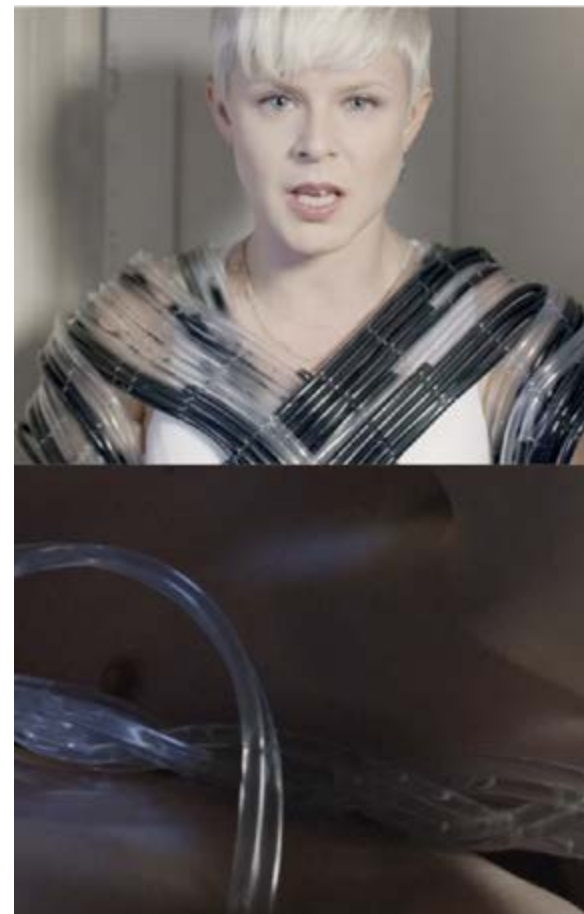
Dream Vase | Marjan Kooroshnia, 2013

The *Dream Vase* project utilizes glass as a canvas for visual analysis. This piece, a two-layer glass vase adorned with a printed surface pattern, reveals an interplay of color and form that evolves with changing light conditions. The surface design on the glass creates "...a pattern that can demonstrate an identical form at daylight as well as at darkness but with two different expressions (Kooroshnia, M., 2013). This dynamic process highlights the versatility of glass as a medium for capturing and reflecting light, while portraying how the material can engage with the viewer on a visceral and sensory level.



Indestructible | Robyn, 2010

GJS Bakker, a Dutch jewelry and industrial-designer, created *Steel Profile* in 1971. This piece, although not directly made of glass, represents a paradigm shift in jewelry design; it is not an adornment, but rather becomes a part of the body.. Described as "not craftsmanship but sublimation of form," Bakker's conceptual design transformed traditional jewelry synthesizing the body in a transformative approach (den Besten, L., n.d.).



Atem Zonen & Pneumacosc | Haus-Rucker-Co, 1967

Haus-Rucker-Co's project, Atem Zonen, is an architectural project that investigates breathing zones, exploring the interaction between individuals and their surrounding air environments in an architectural context. Within this work, Pneumacosc, a collection of accessories designed for these breathing spaces aim to "irritate optical and acoustical perception" (Kelp, Z., n.d.) These projections underscore the artistic potential of breath as a shaping force for us, and by us - analyzing how we design the spaces we create, while inviting us to analyze the relationship between individuals and the air they breathe.



Beer Glasses | Tim Drier, 2021

Scientific glass-blowing methods are utilized to create contemporary beer glasses that transcend functional shapes. In the video "Scientific Glass Blower Makes Beer Glasses" by WIRED, Tim Drier This elaborates on the technical craft of glass-blowing. While the focus is on functionality, the act of blowing breath into the glass holds a dual purpose – shaping the glassware and infusing a personal touch into the creation (WIRED, 2021).



CyberGlass - Glass-blowing Robot | 1997

Merging technology and breathing techniques with glass is demonstrated in the CyberGlass - glass-blowing robot. This innovative project synthesized craftsmanship and automation, where a robot utilizes artificial breath-like mechanisms to manipulate molten glass. Published in 1997, this pioneering venture of the time highlights the potential of technology in redefining traditional crafts. CyberGlass claims its "new glass-blowing machine is capable of reproducing the exact movements of an operator but with much greater repeatability" (Kochan, A., 1997).



ADB Robot | 2008

The intersection of technology and the craftsmanship of glass-blowing is seen through innovative projects that have created a new set of cyborgs, redefining the landscape of glass manufacturing. The ADB Robot, is a glass-blowing robot where the advantages of "lower costs and greater 24/7 non-stop efficiency", have transformed automation in the glass industry (Robotics and Automation for the Glass Industry, n.d.). What was once unable to meet mass production needs, is now possible by the implementation of robotic systems that use artificial breath, human ingenuity, and robotic precision.



Genesis Systems | 2018

The Genesis Systems project is another example of how glass manufacturers have gained a competitive edge by embracing industrial robots. The unpredictability of handling hot glass has been a historical challenge for the robotic industry. However, advancements in robot dexterity, accuracy, and reliability have paved the way for a seamless integration of technology and glass blowing (Petersen, A., 2018). As the synergy between humans and robots becomes increasingly sophisticated, these projects highlight a new era where craftsmanship, technology, and the cyborg come together to redefine the limits in the field of glass manufacturing.

The state of the art in glass exemplifies the versatility of this ancient material and its constant presence in our future. Its use ranges from fashion to art, design, science and the technology fields among others. The projects discussed show the importance of glass in human evolution, as well as centering breath as an eminent tool for creation and further investigation.

The unique qualities of glass have allowed artists to transform ideas into sculptural installations and wearable contemporary fashion that break preconceived notions of how technology and human touch can intertwine. The transformative nature of glass as a material when exposed to heat, light, or breath, expresses concepts that move beyond the physical. Collectively, these projects translate the myriad of ways in which glass and breathing techniques timelessly coexist.

VII. RESEARCH METHODOLOGY

A. MODULARITY & DESIGN

In the fashion industry, the intersection of the environmental impact is closely related to the industry and its foundation blocks that affect cultures throughout the world. Its production accounts for 10% of humanity's carbon emissions, 85% of all textiles go to the dump each year, and approximately 60% of all materials used in fashion are made from plastic (UNECE, 2018 - 2019). Washing clothes also contributes to pollution in our oceans by releasing 500,000 tons of microfibers - the equivalent of 50 billion plastic bottles (Ellen MacArthur Foundation, 2017). These facts, although sad and frustrating, allow us to visualize the effects of our actions as consumers and producers. Therefore, it is important to note that amplifying craftsmanship against mass production, is a powerful message that would allow us to rethink a new way of co-living and co-creating within our environment. The implementation of artificial intelligence and augmented reality are among some of the latest trends that inspire the ability to create multiple variables within a single design almost simultaneously. However, it is still necessary to bring tangible systems forward in order to change consumer behaviors that would benefit the environment in the long run. However, in order to design for our future, we must reference the tools and materials of the past that are still relevant in our present.

The continuous rise of green products is a positive market demand that is promoting modular designs across various industries. More recently, 78 percent of consumers say a "sustainable lifestyle is important to them" (Nielsen IQ, 2022). Therefore, turning towards techniques that are interlinked with enhancing the lifecycle of the products, offers an opportunity to get more out of less material. For example, by working with scientific glass-blowing methods, where technical craftsmanship meets art, "a successful design challenge for the designer is to give the user as much freedom of interpretation as possible while at the same time still being in control of the quality of the design" (Stam, L. and Eggink, W., 2014). This shapes the idea that having direct input in the outcome solidifies the connection between the user, the environment, and the ultimate experience.

Another tool that builds upon this co-creative method is the implementation of generative design where there is "no single solution; instead, there are multiple great solutions" that can be visualized through the use of interlocking systems (What is Generative Design: Tools Software, 2023). This speeds up the process to create alternatives to designs that can be implemented more efficiently. In Daily Sketches by Zach Lieberman, short generative animations are built by using code to formulate visuals that can be easily iterated (Gross, B. et al., no date). Alternatively, in projects like Abstract_, the customer's personal story, facial expressions, and rhythm of the keystrokes are mapped onto a textile with the use of software



(Gross, B. et al., no date). This promotes the consistent need for customization while being able to make rapid design changes that become available due to technological advancements but could be even more rapid through craftsmanship depending on the material.

Modular systems go hand in hand with generative design for the vast capabilities they offer. They are closely connected to the concept of "minimum inventory and maximum diversity," which is a "model closely associated with architecture, engineering and the sciences" (Hur, E.S. and Thomas, B.G., 2011). In fashion, these types of ideas can be seen in projects like Fragmented Textiles by Van Balgooi and Soepboer (2009) where interlocking systems are implemented with geometric patterns to provide clothing that can be worn in a wide variety of arrangements. The user is able to customize the design to fit their unique aesthetic providing a "system of fashion that was not just efficient but essentially waste free" (Hur, E.S. and Thomas, B.G., 2011).

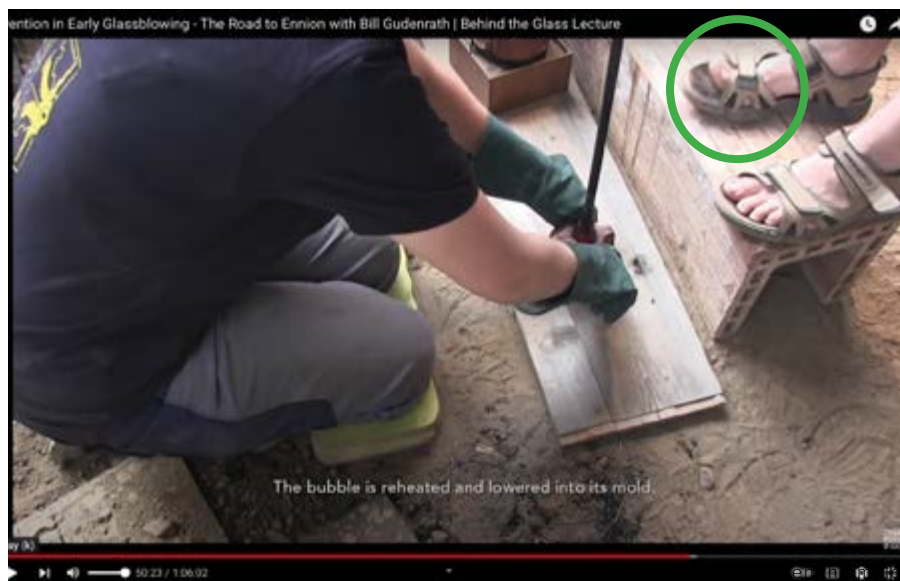
We are seeing that the shift towards more sustainable products that offer versatility continues to rise alongside increased environmental awareness. In a recent study, climate change was the top concern for 45% of those surveyed, with more consumers "choosing to buy more socially responsible and sustainable products" (Nielsen IQ, 2022). This opens up the opportunity to merge fashionable

modular systems with craftsmanship. Another interesting perspective is that although it is no secret that our bodies age and transform through time in relation to our lifestyle (Aging changes in body shape: Medlineplus medical encyclopedia (no date) MedlinePlus), once we reach maturity, some clothing and accessories can be worn for countless years and can be passed down through generations. Creating sustainable, generative designs while implementing interlocking systems that discard the need for sizes and reduce manufacturing techniques as well as additional trims and hardware is at the core of the vision.

The aim of this project is to analyze the bridge between digital and analogue techniques by exploring the connection between the unconscious act of breathing and the conscious process of glass blowing, positioning breath as an influential shaping tool. By implementing modularity with enhanced structural stability and ease of assembly, endless possibilities become available and designs can be tested and produced more efficiently. Furthermore, the ability to build upon structures as desired offers the user the opportunity to apply their own creativity as a tool for connection.

B. LANGUAGE

Glass-blowing bridges various aspects of physical and non-physical language. It is a unique craft where the artist must learn how to connect with the material, while embracing the power of collaboration. Developing the skills necessary to work with glass forms a critical bridge between technical expertise, artistry, and non-verbal communication. In Bill Gudenrath's lecture, "Early Glassblowing - The Road to Ennion," the profound significance of this non-verbal language is underscored in the context of teamwork (Invention in Early Glassblowing - The Road to Ennion with Bill Gudenrath | Behind the Glass Lecture, 2015). Artisans must work in teams and engage in a non-verbal choreography where each movement and gesture decipher specific time sensitive messages as the glass must be manipulated before it cools. The glass-blower cannot speak while blowing glass, and must be attentive to the changes in heat and color in order to know when the glass is ready to be worked on. Because of this, they must use their body to send signals. For example, with soft glass working techniques, the one who is blowing through the pipe taps one's foot to signal that the glass is ready to be removed from the mold. This silent, simple, yet precise cue helps us analyze how movement connects the body with the material without physically touching, the artisan must learn to feel the glass.



Gudenrath's mention of lifting the toes as a "universal sign for "open the mold" " also highlights the reliance on non-verbal communication, merging technical proficiency and intuitive collaboration. Additionally, the application of conscious breathing techniques to shape the glass serve as sensory mechanisms creating a co-creative relationship between the creator and the glass itself. This process allows the artisans to feel the heat of the glass pushing against their own breath, where the material finds a way to communicate when it is ready.

As described throughout this text, scientific glass-blowing requires highly technical skills that embody a precise language between scientists, craftsmen, and glass in order to be able to succeed in experiments and discoveries. In The Johns Hopkins Science Review in 1951, Lynn Poole mentions the specifications that glass-blowers must adhere to in an unparalleled level of precision, to the thousandth of an inch where attention to detail is essential for the functionality and success of scientific apparatuses (Poole et al., 1951). Glass is reflective of this process, for it doesn't hide mistakes.

The language between maker and material, physical and non-physical, can be critically analyzed in Donna Haraway's insightful quote, "Cyborgs and companion species each bring together the human and non-human, the organic and technological, carbon and silicon, freedom and structure, history and myth, the rich and the poor, the state and the subject, diversity and depletion, modernity and postmodernity, and name and culture in unexpected ways"

(Haraway, D., 2003) This compelling thought process highlights the symbiotic language between breath, glass, and technology, manifesting the human-non-human interplay that Haraway references.

Breathing, an inherently organic and life-sustaining aspect, becomes a powerful transformative tool of creation that collaborates with the inorganic nature of glass - blending dichotomies between these technologies. In this artistic context, glass becomes a companion species as a metaphorical cyborg element, embodying the union of the human and non-human, organic and technical, structure and freedom, and therefore creating an unexpected and transformative narrative in the art and science of glass-blowing.



C. MULTI-SENSORY EXPERIENCE

The nature of craftsmanship involves dexterity throughout many practices. In glass-blowing, the technical artistry along with verbal and non-verbal techniques create a multi-sensory experience that transcends visual perception, where seeing becomes feeling. In learning how to work with glass, one must learn how to play with fire. “Keine angst”, no fear, became a constant reminder by mentor Günther Mausz. The initial reaction that fire creates is one of fright as a result of the proximity to the body, knowing that the wrong move can lead to getting burned. However, scientific glass-blowing teaches how to connect all the senses in unparalleled ways. It demands keen awareness of one’s body, conscious movement and touch, noticing colors in both flame and glass to understand timing and manipulation, as well as listening to the strength of gas and oxygen being released, all while constantly rotating glass rods in order to work with gravity. It becomes a mindful practice that embodies analytical and artistic thinking processes that harness technical skills and a deep sensory understanding of this medium.

Flameworking is a technical aspect of glass craftsmanship that requires visual literacy. The artisan must observe variations in color and size to be able to discern the temperature. For example, a white flame represents a high temperature that allows the glass to melt and it can vary in width depending on what it is being created. A soft yellow-orange flame is used to warm up the glass and spread the heat to avoid breakage. Each variation signifies distinct conditions in the glassworking process. The significance of the white flame, burning two parts oxygen to one part gas, highlights the nuanced control required in the many aspects of this craft (WIRED, 2021). Altogether, the artisan must be fully present in order to notice these color changes, further exemplifying the importance of keen visual senses.



Understanding glass is a learning experience that becomes unique to each individual, in a sense, it is reflective of breath - it is never the same. Yet the transparent qualities of glass allows us to see instantaneously how specific breathing techniques transform it, connecting craftsmanship to scientific inquiry of seeing vs. feeling. This is visualized through early experiments like the Common Air, conducted by Joseph Priestley in the 1760s, as referenced in “Laboratory Scientific Glassblowing: Advanced Techniques And Glass Blowing Place in History” (LePinnet, P., no date). Priestley was described as a man of “enlightenment”, he taught English Grammar and delved in chemistry experiments during his spare time (LePinnet, P., pg. 7, no date). His approach allowed him to intuitively understand that there was more to air than could be seen or touched, and the characteristics of glass made it possible to do so. This marked an historical event that showed the importance of blending craftsmanship and science to find the unexpected.

In this collaborative context, the making of early eye prosthetics illustrates how craftsmanship extends beyond artistry. Glass eyes crafted for anatomical models “encapsulated a conceptualization shared across surgical and artisanal practices that the body was a kind of material, equivalent to the matter craftsmen worked with” and “it encouraged a re-evaluation of sensory literacy, fostering a way of seeing that also entailed touching” (Bigotti, F., 2021). This exploration is a vivid example where the artisan’s hands become a conduit for a multi-sensory experience extending beyond the ordinary.

The connection between material and body in glass-blowing is deeply rooted in the technical and artistic skills of this craft. In the study “Embodied Knowledge in Glassblowing: The Experience of Meaning and the Struggle Towards Proficiency,” Erin O’Connor explores this relationship by analyzing the learning process where beginner craftsmen transition from utilizing shaping instruments, to the instruments becoming an extension of themselves. O’Connor

references Michael Polanyi’s concept in Personal Knowledge, where tools cease to be mere objects and instead become “part of ourselves”, especially since they allow a glass-blower to feel the glass without direct touch (Polanyi, 1962, 59). O’Connor’s personal experience while learning to work with glass is an example of what Polanyi terms “a subsidiary awareness of the blowpipe” (O’Connor, E., 2021, 4). This journey marks a pivotal moment in an artisan’s experience, where external manipulation becomes an internal understanding of the process, the artisan’s body and the material co-create beyond the senses.

By centering breath as the connective tool, the bridge between physiological rhythms and emotional well-being is questioned. According to the study “How heart rate variability affects emotion regulation brain networks” by Mather and Thayer (2018), individuals with high heart rate variability (HRV) experience better emotional well-being. Breathing influences HRV, making it a viable assumption that specific glass-blowing techniques could be linked to cognitive thinking, rational decision making, mindful movement, and overall calmness. In this study, breathing techniques enhanced functional connectivity in brain networks which were linked to emotional well-being. HRV biofeedback sessions involving resonance-paced breathing at a frequency of 0.1 Hz were analyzed, and have shown to reduce anxiety and enhance performance in various domains (Mather et. al, 2018). This frequency aligns with meditative practices where breathing slows down to around a 10-second rate.

Whether this connection is seen by chance or analyzed through science, it is imminent to note the value of craftsmanship as an essential part of our present and our collective evolution in an era of digitalization. Working with our bodies is not only a tool for emotional regulation, but the connection between breath, body, and material is essential and perhaps beneficial to our overall health.



VIII. EXPERIMENTAL METHODOLOGY

A. LEARNING PROCESS

Scientific glass-blowing is a skill that requires years to develop and is a particular process where failure becomes acceptance. The tolerance for error is so minute, that at any moment, starting over can become an option. Whether burning oneself with the flame or glass, for its color appearance stays the same even while at high temperatures, combining pieces at the wrong time, which could mean a difference in seconds, or finding cracks in a piece that has been worked for hours after removing from the kiln, resilience is necessary in order to become antifragile.

Mentored by Günther Mausz, a Linz based scientific glass-blower that has been working in this field for over thirty five years, the foundational skills were developed through a period of two years. Mausz became an exemplary craftsman demonstrating not only the magnitude of seemingly simple techniques that are rooted in complicated pieces, but incredible endurance in mindset by letting go of mistakes quickly while showcasing the power of conscious breathing techniques in connection with mindful movement.

In the image below, Günther is finishing a large glass bubble that has been blown with continuous breath while constantly rotating the points at both ends of the piece at the same rate, maintaining alignment, and feeling the thickness of the material through the heat being pushed back from the glass to the breath. Being able to make such work takes years of practice.



TOOLS & EQUIPMENT

Made from brass, stainless steel, and graphite, glass-blowing tools become extensions of the body as they manipulate glass. These tools are necessary and the quality must meet industry standards in order to maintain safety at all times.



HEXAGONAL REAMERS

POINTED REAMER



GLASS-BLOWING HOSE



BOROTRUVIEW PROTECTIVE GLASSES



KEVLAR GLOVES



DIGITAL CALIPER



MESURING CALIPER



GLASS CUTTING KNIFE



FORCEPS



FLAT TWEEZERS



CARBON PLATE W/HANDLE + W/OUT HANDLE



BENCH BURNER



HAND TORCH

B. CREATING POINTS

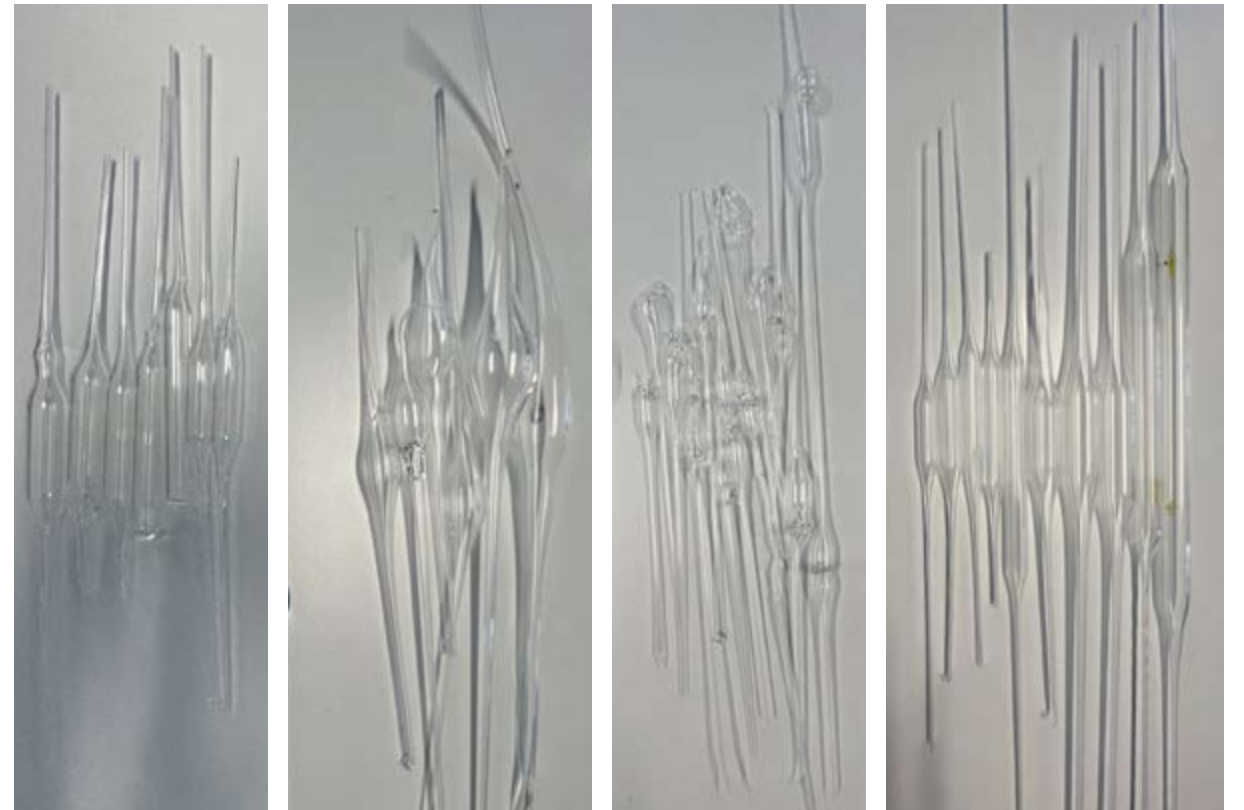
Starting with borosilicate glass tubes, heated sections are pulled to create long points that are used as handles. With only ten working seconds before the glass cools, this process entails precision and stability in order to keep the points straight while maintaining a wall width that can handle the weight of the middle section when manipulated.



Günther Making Points

This process shows the beginning stages from curved irregular points to straighter points in different tubing widths over a period of three to six months.

Points Practice



A variety of borosilicate glass tube sizes were tested while practicing and developing this technique. Points became stronger and straighter after 3 months. This foundational skill is necessary in all flame-working techniques.

Points Practice



C. BENDING

Bending glass tubes at different angles is another foundational technique that allows a variety of structures to be created. However, this seemingly simple step requires three steps that must be meticulously performed within ten seconds:

- Pull softly the heated area
- Bend at the desired degree
- Blow slowly so that the width of the tube is homogeneous throughout.



Günther Bending Rods

Irregular bends were created during a period of three months before being able to make more consistent shapes.

Bending Practice



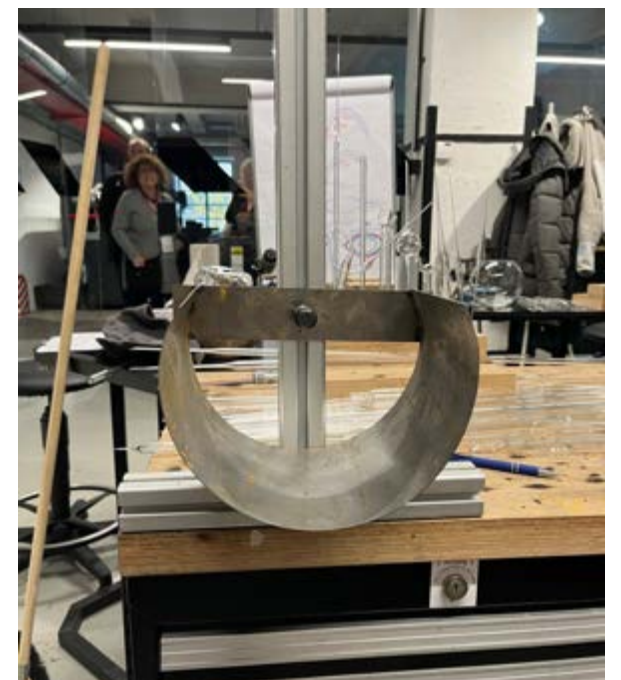
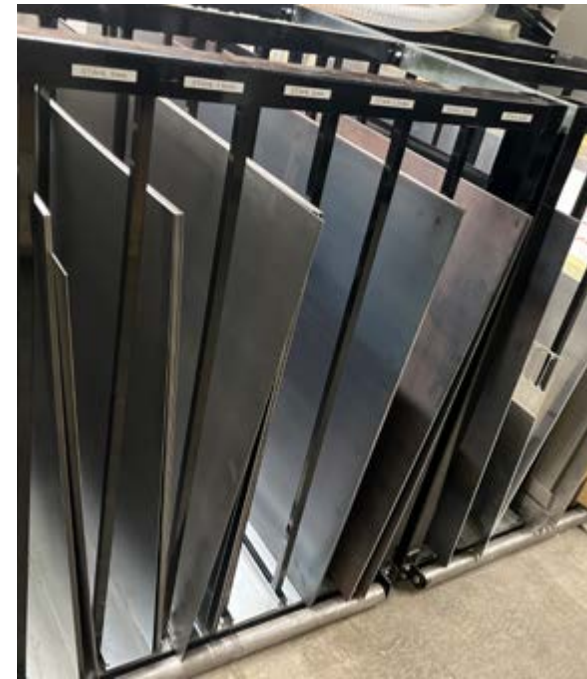
D. CURVING

Sections of glass are melted while applying the previous techniques mentioned. In this case, a larger area of glass is stretched and bent at the desired degree. In the below images, the progression of curve improvement can be seen from left to right. In order to achieve a more consistent curve, steel plates were bent to create a mold for repetitive curve formations.

Curving Exploration



Steel Plate Mold Exploration



E. GLASS BUBBLE PROCESS

Creating glass bubbles may appear to be uncomplicated at first sight, a simple round circle appears while blowing from one end of the points. However, this technique encompasses various movements simultaneously, where breath plays a major role in maintaining a symmetrical shape.

When the glass section reaches a melting point that can be felt through movement, constant rotation is key as gravity will make the molten glass fall, and the wall thickness must be kept consistent throughout so that the resulting bubble is strong. Within the ten working seconds, the glass-blower must blow through the open end point with enough strength to expand the glass, but without breaking it. Breathing must be steady and controlled, while maintaining rotation and watching for through the center of the point for alignment and wall thickness. Altogether, blowing a glass bubble requires mindful movement and awareness of all the elements combined.



Glass is melted and pulled to create straight points that are used as handles on both ends of the glass tube. One of the ends is separated from the tube and closed.



The middle section is reheated with constant rotation, this will determine the size of the glass bubble.



When the glass color changes to red-orange, it is ready to be blown from the open end of the points. Feeling with breath, heat creates resistance to signal a stopping point.



GLASS BUBBLE PRACTICE

Over a period of six months, hundreds of glass bubbles were blown in order to achieve a continuous desired result, aiming to create repetitive forms in size and shape. Starting with single bubbles to blowing two bubbles within the same tube to test alignment, while adding a curve through the center, this process tested one's resilience and perseverance.

Symmetry Experimentation



Double Bubble Experimentation



Curve + Bubble Experimentation



Twist + Bubble Experimentation



Bubble Size Experimentation



Continuous practice threaded by countless failed attempts, lead to consistent results after a period of about six to nine months. This technique required strong end points for stability, while understanding how to apply breath as a shaping tool to mold and feel the wall thickness. This challenge showed improvement after hundreds of bubbles were placed together in alignment.



F. BREATHING VISUALIZATIONS

Breathing is an extension of our physiology, embodying inherent qualities that define our health, both mental and physical. In this artistic context, breathing techniques are explored as shaping tools to visualize these states. From slow to fast paced breathing symbolizing calmness, fear, or anxiety. This method is used as a reference point from which this project is born and analyzes the resulting shape as seen throughout a variety of glass bubbles.



Slow Exhale + Inhale

Fast Exhale + Inhale

Long Exhale + Inhale + Pull

Long Exhale + Pull + Inhale

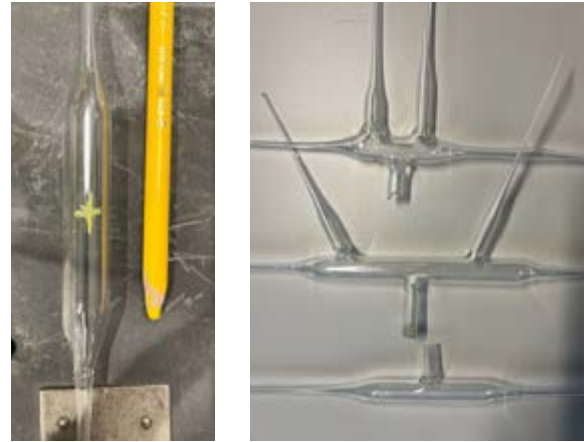


Slow & Calm Exhale + Inhale Pull

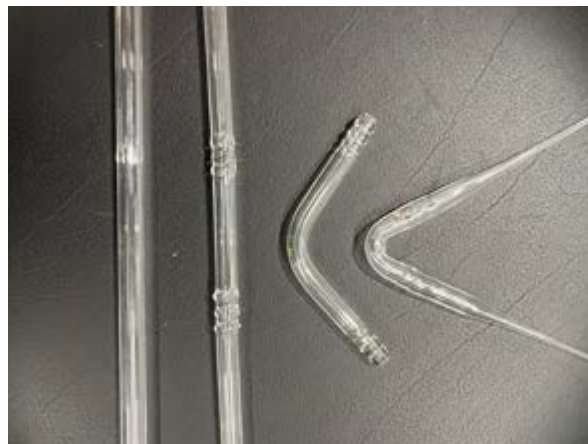
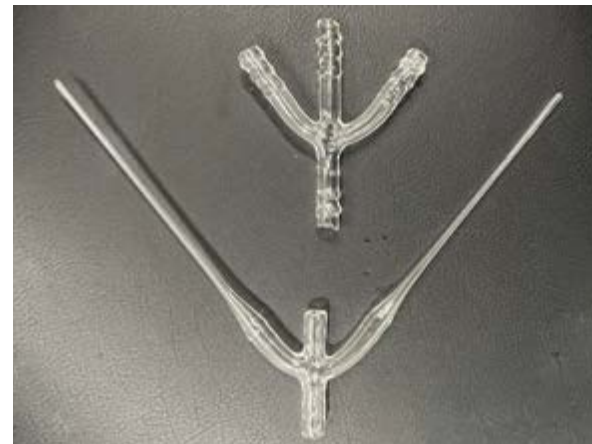
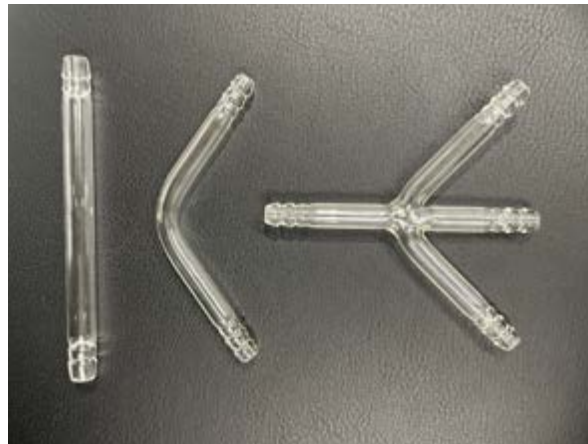
Fast & Anxious Exhale + Inhale + Pull

G. CONNECTION EXPERIMENTATION

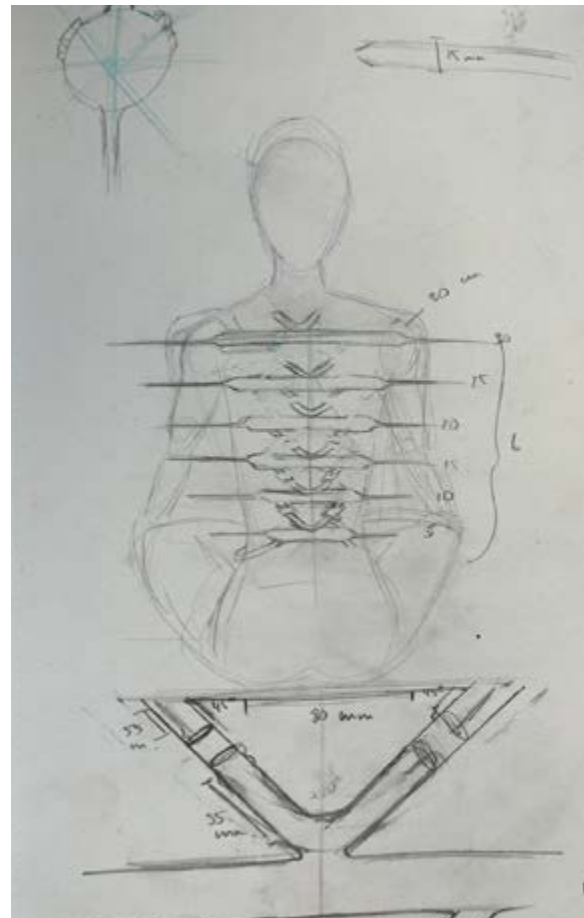
In fashion, glass is not commonly used as a wearable material for its structure and fragility do not allow for free movement. Because of this, multiple connection methods were tested in order to understand the foreseeable options, and design a method from which to build from. The advantage that glass can be manipulated into multiple forms allowed us to test angles and shapes that are not easily achievable through digital processes such as 3D printing.



Using a grease pencil made from wax, specific sections are marked on the glass in order to be able to see placement when the flame heats the area. This is crucial for continuity and assembly.

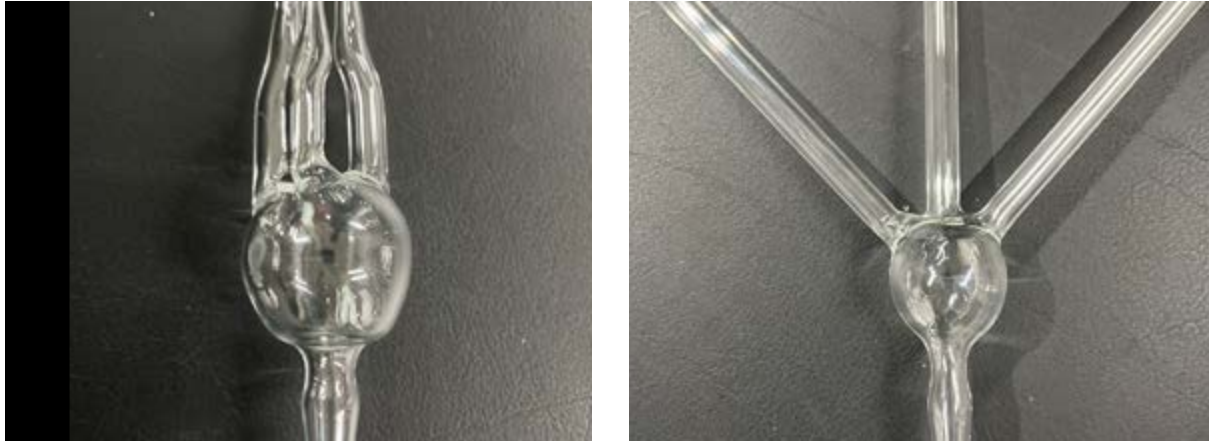


Glass tubes with “olives”, a term used to describe small areas of thickened glass that create a slight curve, are used as joints to create connection points. The center sections were also curved to test overall angle and direction.

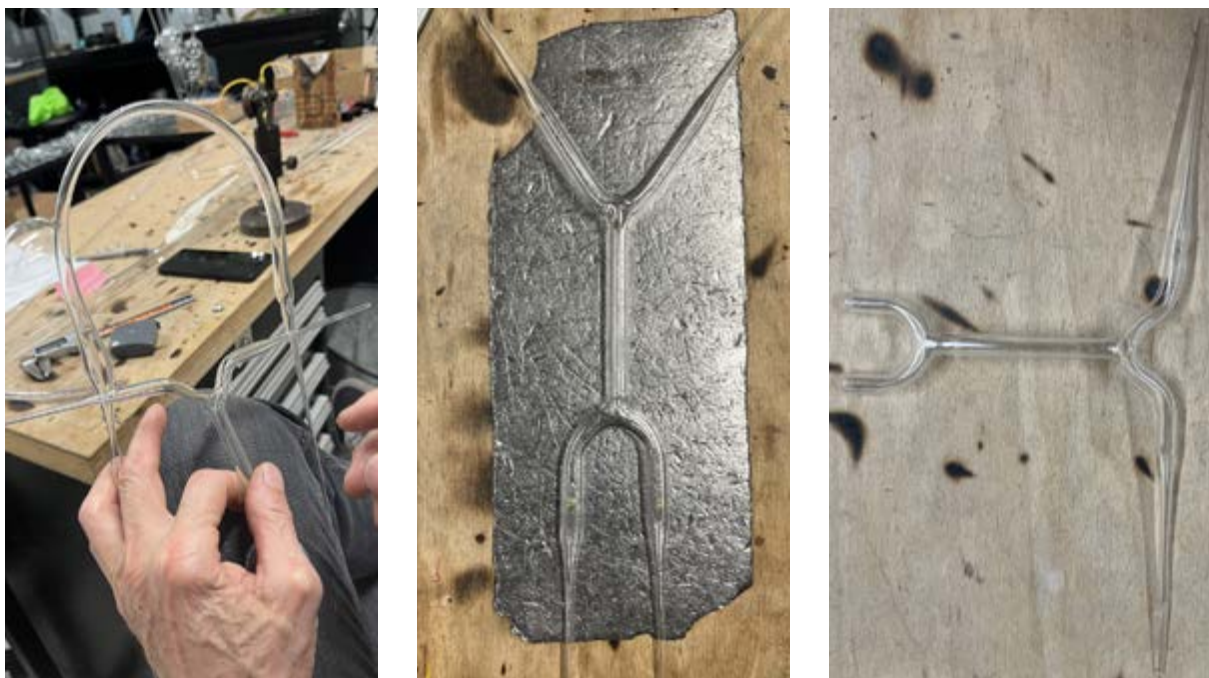


The creative design process aimed to visualize scientific glass structures on the body along with connection points.

Glass bubbles were connected with tubes at different angles, this gave an understanding of the techniques required and the possible building blocks.



In addition to creating directional joints, curves, lines and bent tubes were also connected to find new ways of intersection. This method highlights technical scientific glass-blowing skills and merges them with fashion design, in a sense it mirrors hardware development for jewelry and accessories.



Sustainability was also an important aspect of this undertaking. Scraps from previous scientific glass projects built by Günther Mausz were used as the in-between pieces to connect parts without the need of additional material. This saved time and resources, and streamlined the experimental process.



H. MODULARITY + FLEXIBILITY EXPERIMENTATION

Modularity has been one of the core values of the design process. In the search for solutions to connect glass pieces while adding versatility, the connection points were adjusted at different angles. This step opened up new possibilities for design on the body while adding flexible PVC tubing between the joints to create interlocking systems that allowed for movement.



Added flexibility unlocked a new set of boundaries for wearable glass in fashion design.



I. SKETCH TO DESIGN EXPERIMENTATION

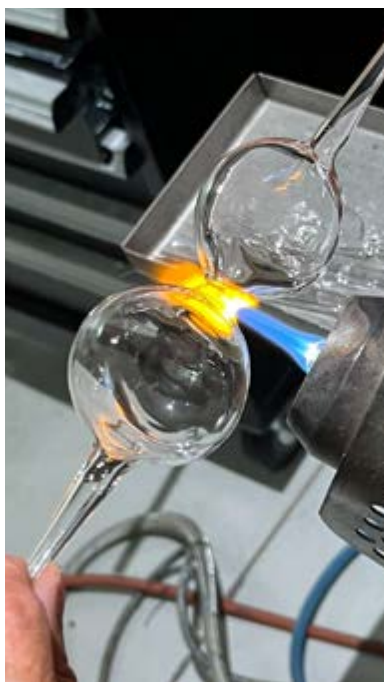
Learning how to create basic shapes using scientific glass-blowing methods led to a journey filled with failure, testing one's resilience, and determination. As a result, becoming antifragile to the process meant that designing wearable glass in combination with breathing visualizations, created a new set of sketching in an artistic concept.

MINDFUL INSTRUMENT



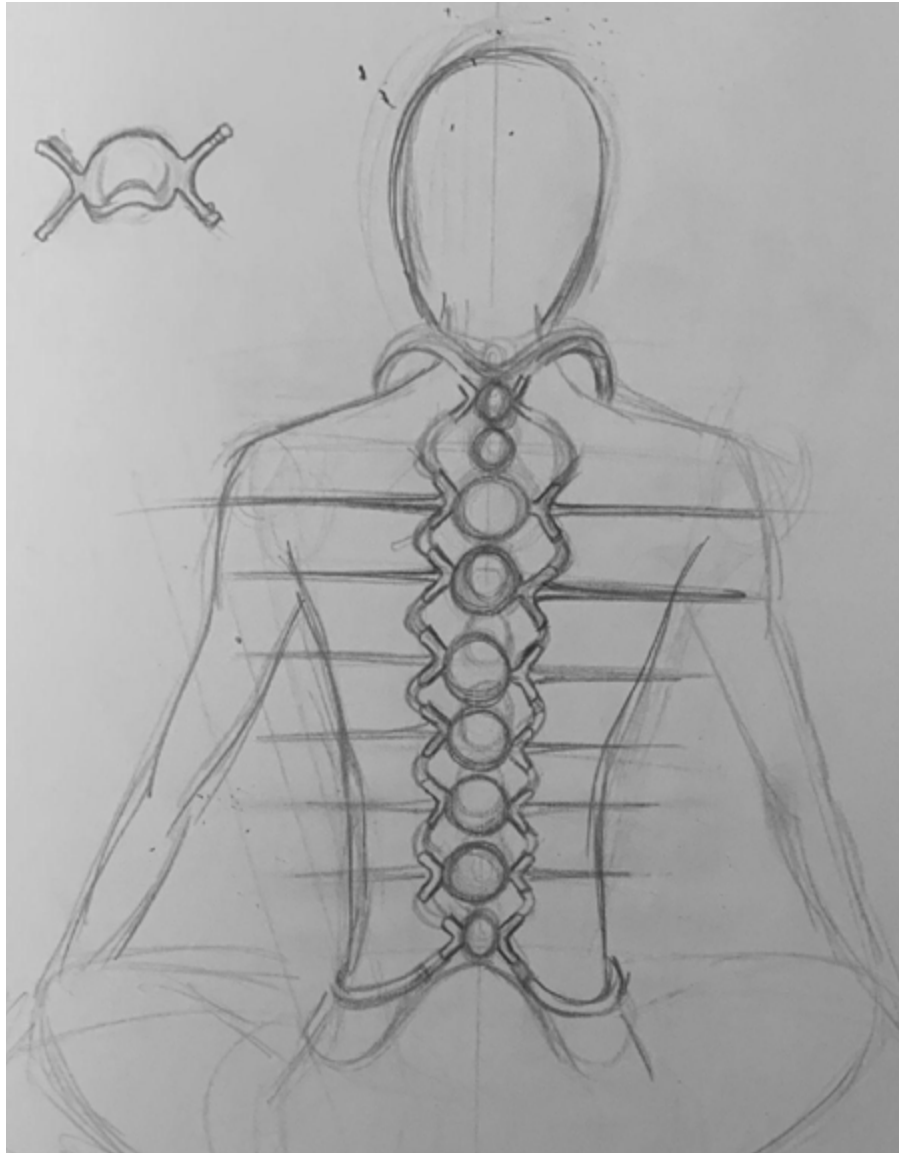
The placement of glass bubbles on the body was centered around alignment and energetic points referencing how breath travels through the body.

Glass bubbles and curves were connected at specific intersection points to follow the sketches.



Glass accessory in relation to the sketch resembles accuracy in rendering. This places a key focus on the power of analogue techniques in craftsmanship versus digital implementation.

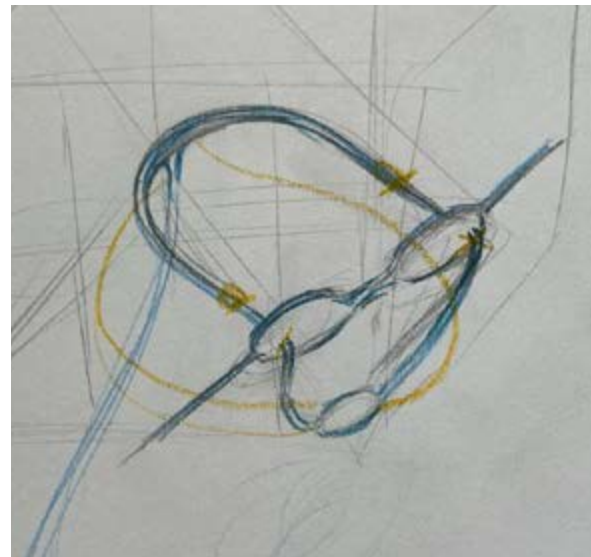
SPINAL BACK BODICE



The sketching process required an understanding of the available shapes.

During the assembly process, modularity was tested during fit as well as flexibility.





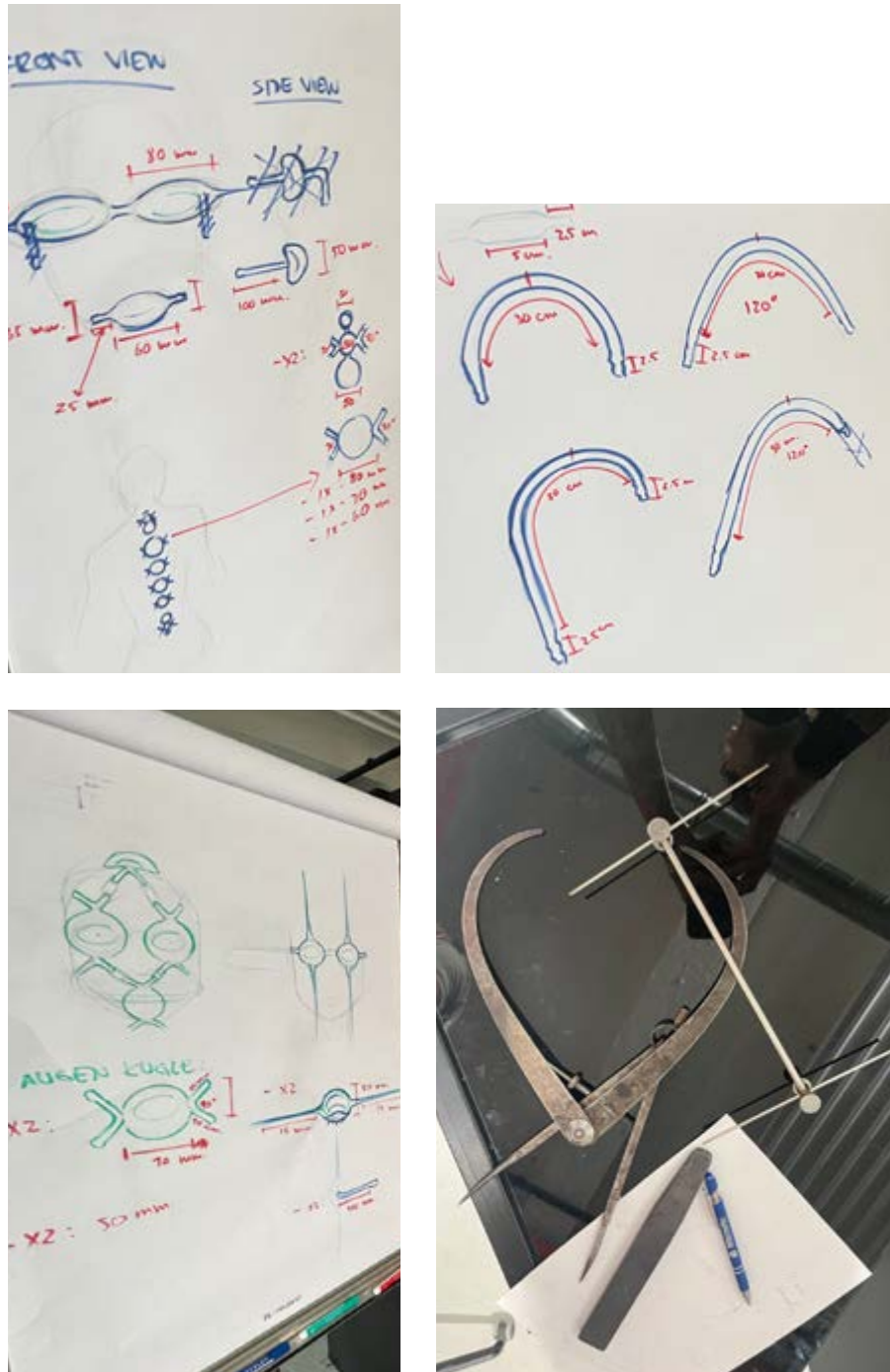
GLASSES

Developing glasses in this artistic context combines an inhale and an exhale in order to make the concave curve that creates space for the eye. The overall shape follows basic shapes as a starting point.



J. TECHNICAL COMMUNICATION

Scientific glass-blowing is a craft that requires precise measurements and techniques. In order to create desired shapes, technical communication had to be used to translate visual ideas into tangible objects. For example, the size of the bubbles was a basic requirement, but when the shape became more complex, the need for other measurements of distance, angle and placement were also necessary. This allowed for more accurate interpretation and repetition in desired shapes.



K. SHAPE EXPERIMENTATION

Scientific glass-blowing is a craft that requires precise measurements and techniques. In order to create desired shapes, technical communication had to be used to translate visual ideas into tangible objects. For example, the size of the bubbles was a basic requirement, but when the shape became more complex, the need for other measurements of distance, angle and placement were also necessary. This allowed for more accurate interpretation and repetition in desired shapes.



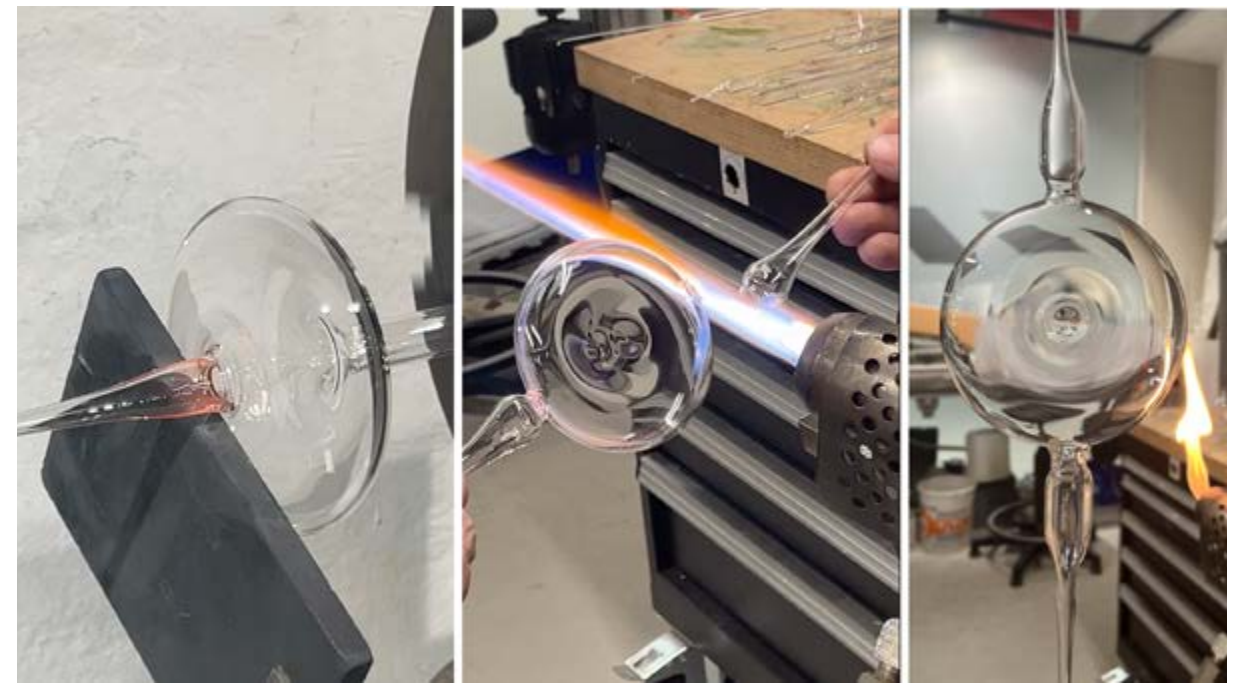
LARGE BUBBLE WITH INHALE + EXHALE COMBINATION



COMBINED BUBBLES WITH SOFT INHALE AND CURVED CENTER.



FLAT BUBBLE EXPLORATION, WITH VERTICAL COMPRESSION, PULL + INHALE



FLAT BUBBLE EXPLORATION WITH HORIZONTAL COMPRESSION & CENTRAL CURVE



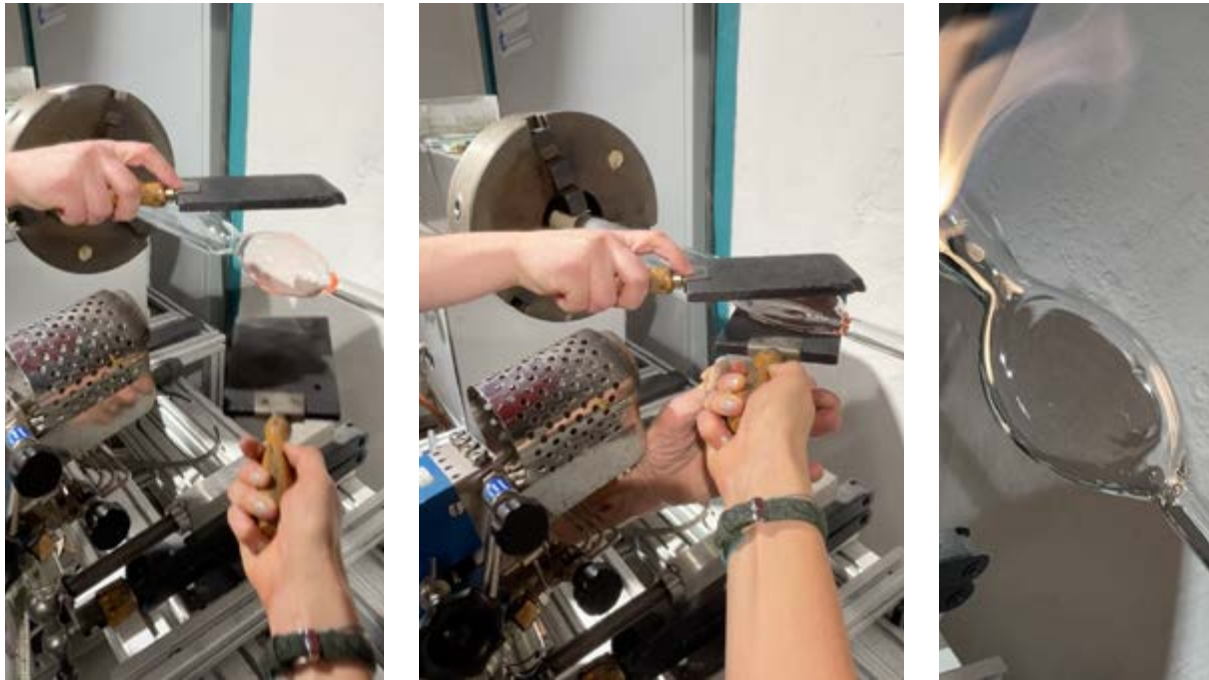
This working method visualized entirely new shapes for the first time. The steps utilized here are not common in scientific glass-blowing techniques since structure and precision have a higher hierarchy than organic forms.

L. ANTIFRAGILITY

Glass-blowing opens up a path full of unexpected challenges. The learning process requires extended periods of time and trials that seem to lead to nowhere. This is one of the reasons why this is a dying art where mistakes and failures must be accepted and embraced. Blowing glass bubbles is barely the beginning, however, as shapes are connected and transformed,

the “wrong” move or timing creates a plethora of visualizations - although they may not be ultimately useful as a wearable, they provide a myriad of inspiration. Glass is twisted, pulled, joined, and broken, yet the skills become embedded in one’s body, while becoming antifragile.

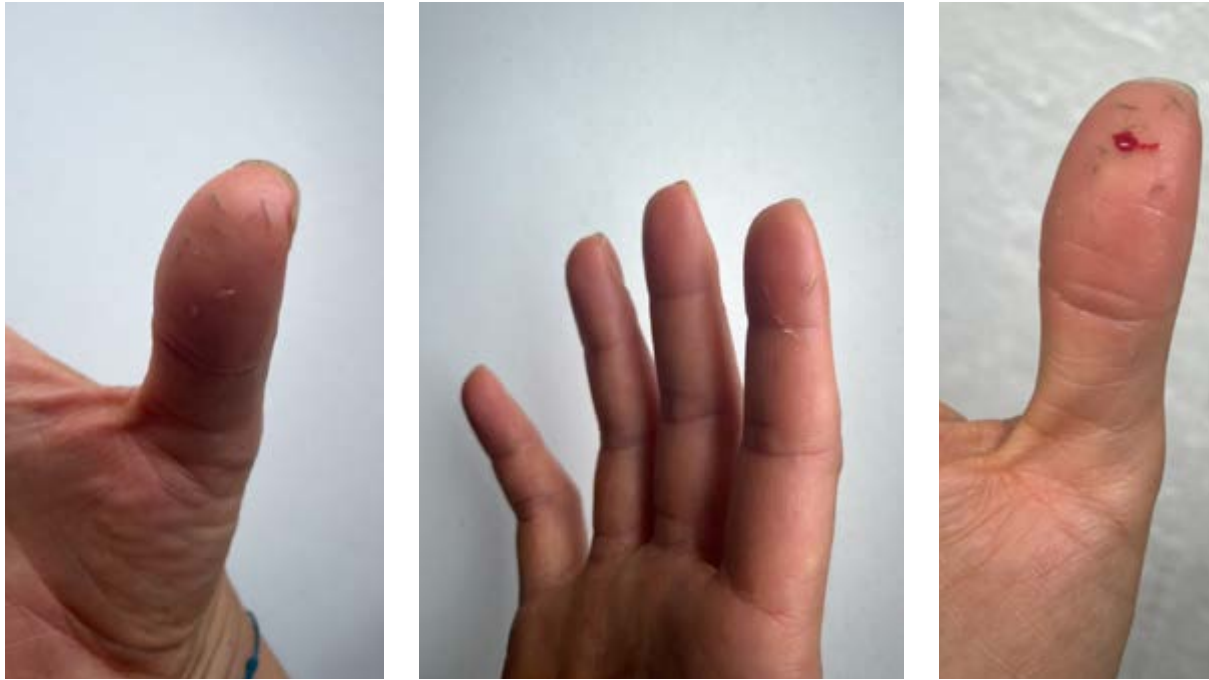
FLAT BUBBLE EXPLORATION + ASSISTED COMPRESSION + GRAVITY FOR CURVE



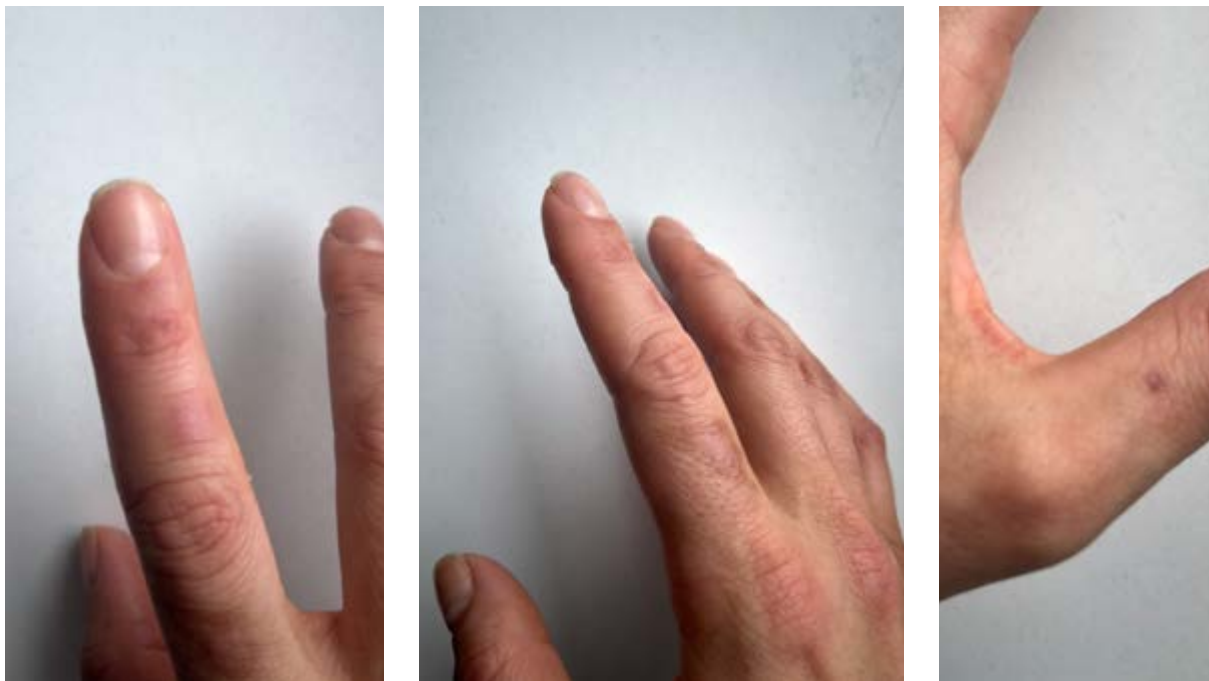
FLAT BUBBLE EXPLORATION + ASSISTED COMPRESSION + GRAVITY FOR CURVE



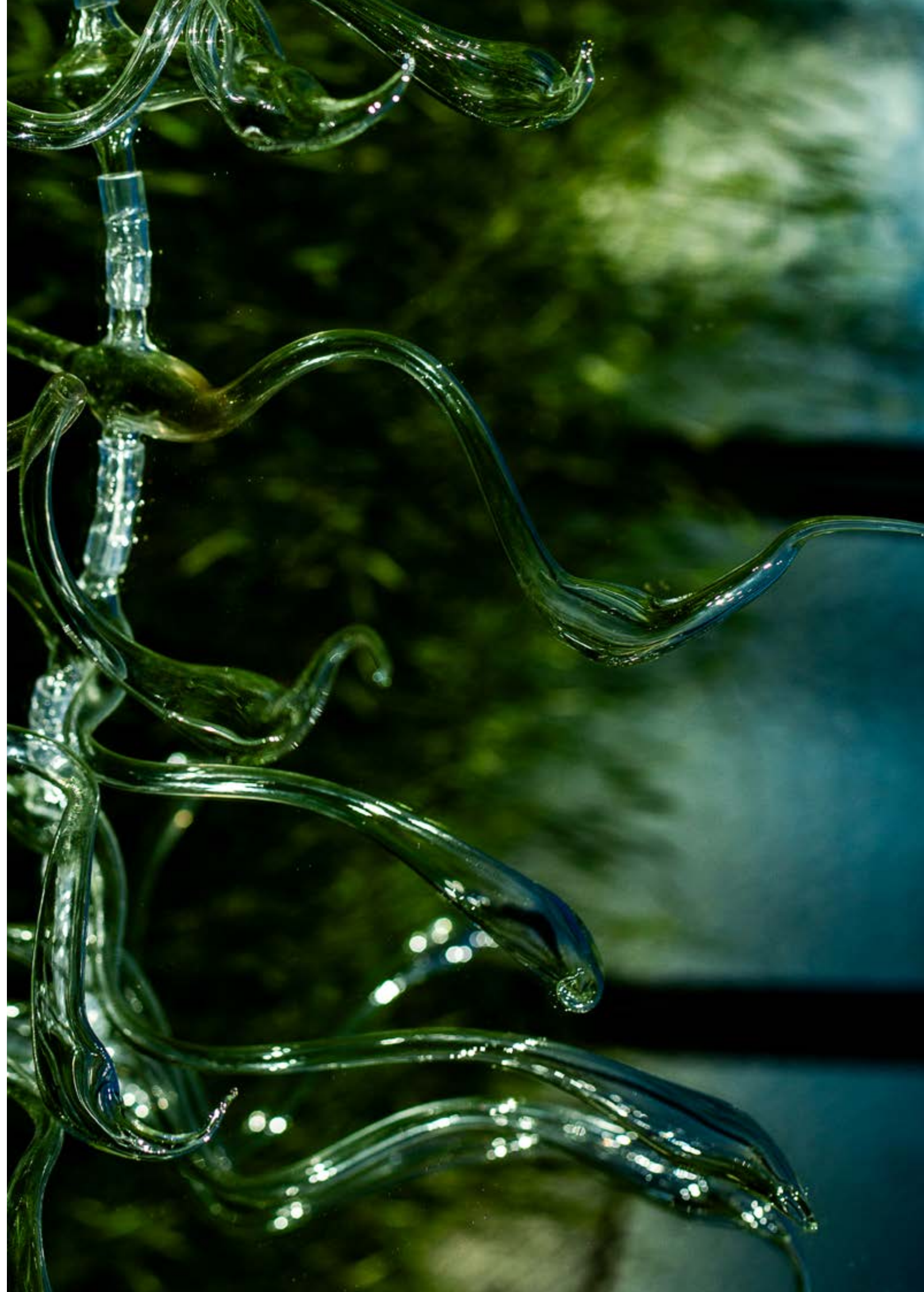
CUTS



BURNS



Accidents are a part of the learning process, especially in glass blowing. The first burn stings very vividly and can feel stronger when our bodies are in panic. However, I have experienced the power of resilience that glass teaches for I have gotten burned quite often. This journey led me to react to this situations differently, instead of panicking, I learned to breath through the pain and over a period of months, without actually counting, I realized that the burns I thought would create blisters or marks from the beginning stages, were healing in a few days and my body was not reactive. Here is where mindful awareness became essential, and a lesson that is imperative in today's world.





IX. DESIGN RESULTS

Pulmonaut critically analyzes breathing techniques in an artistic context. The concept is inspired by a world where we collectively co-create, similarly to how craftsmen work together in glass-blowing, while highlighting the power of breath and its impact on our body and our surroundings. By designing wearable glass, slow movement is forced to prevent breakage, triggering the model's breathing to also slow down as well as the audience's. This experiment proves the concept of this thesis, where breathing is a central aspect of connection and mindful awareness.

The designs in this project are inspired by our own bodies with a speculative vision of a present future. Humanity evolution is constantly in the search for life on other planets, taking astronauts to explore space and researching breathing conditions. However, what if we were to take the initiative to breathe with this sense of awareness here - while walking, while moving, while thinking, while feeling. By forcing us to focus on our own breath, Pulmonaut is a collection of wearable flexible glass instruments that inspire us to explore our own breathing technology.



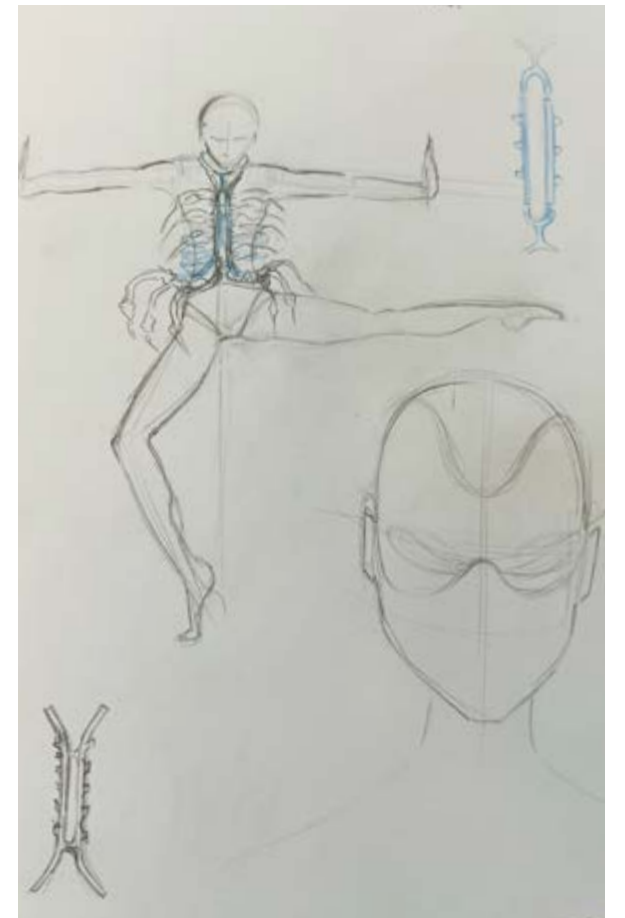
OZEUZ



Ozeuz highlights the body while synthesizing the skeletal system and organs with the structure of a wearable form resulting in an exo-skeleton. Here, the challenge of movement is represented but solved through the flexible joints that trigger a walking meditation with conscious breathing.

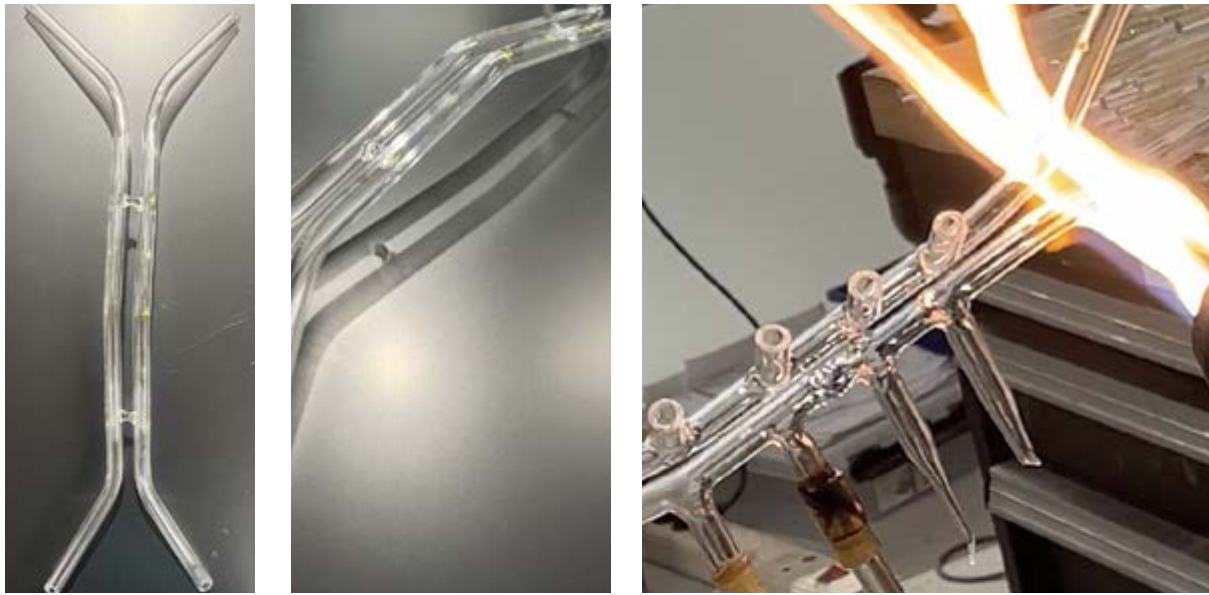


SKETCH DEVELOPMENT

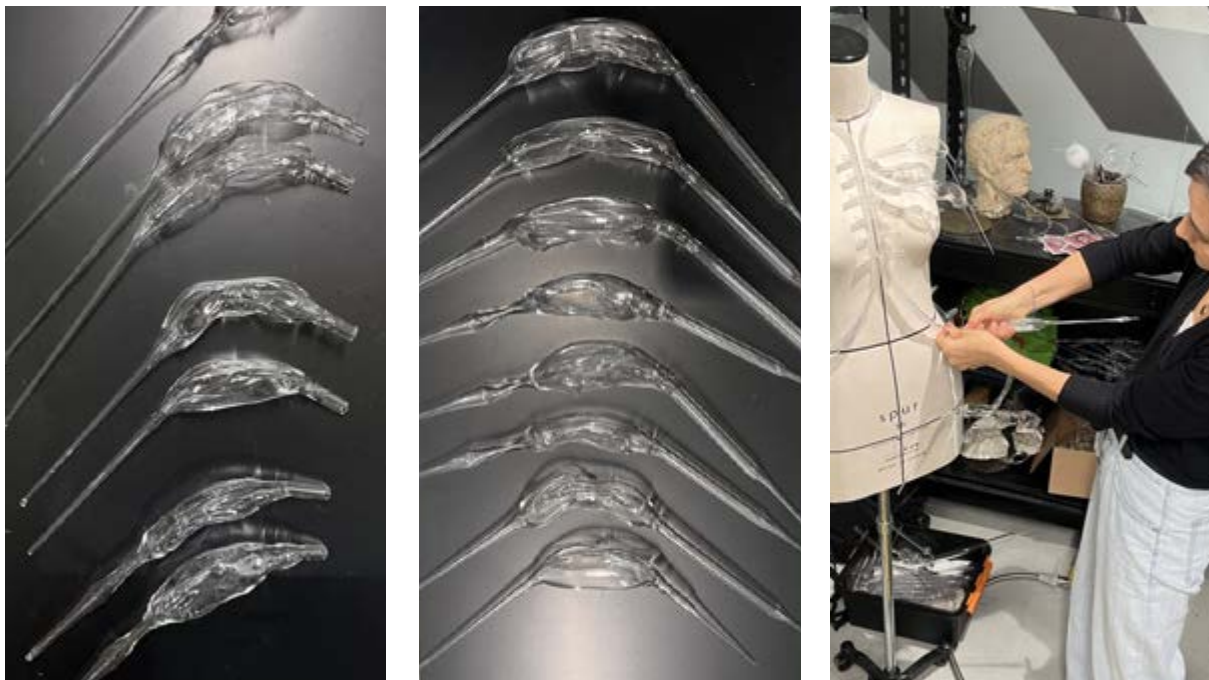




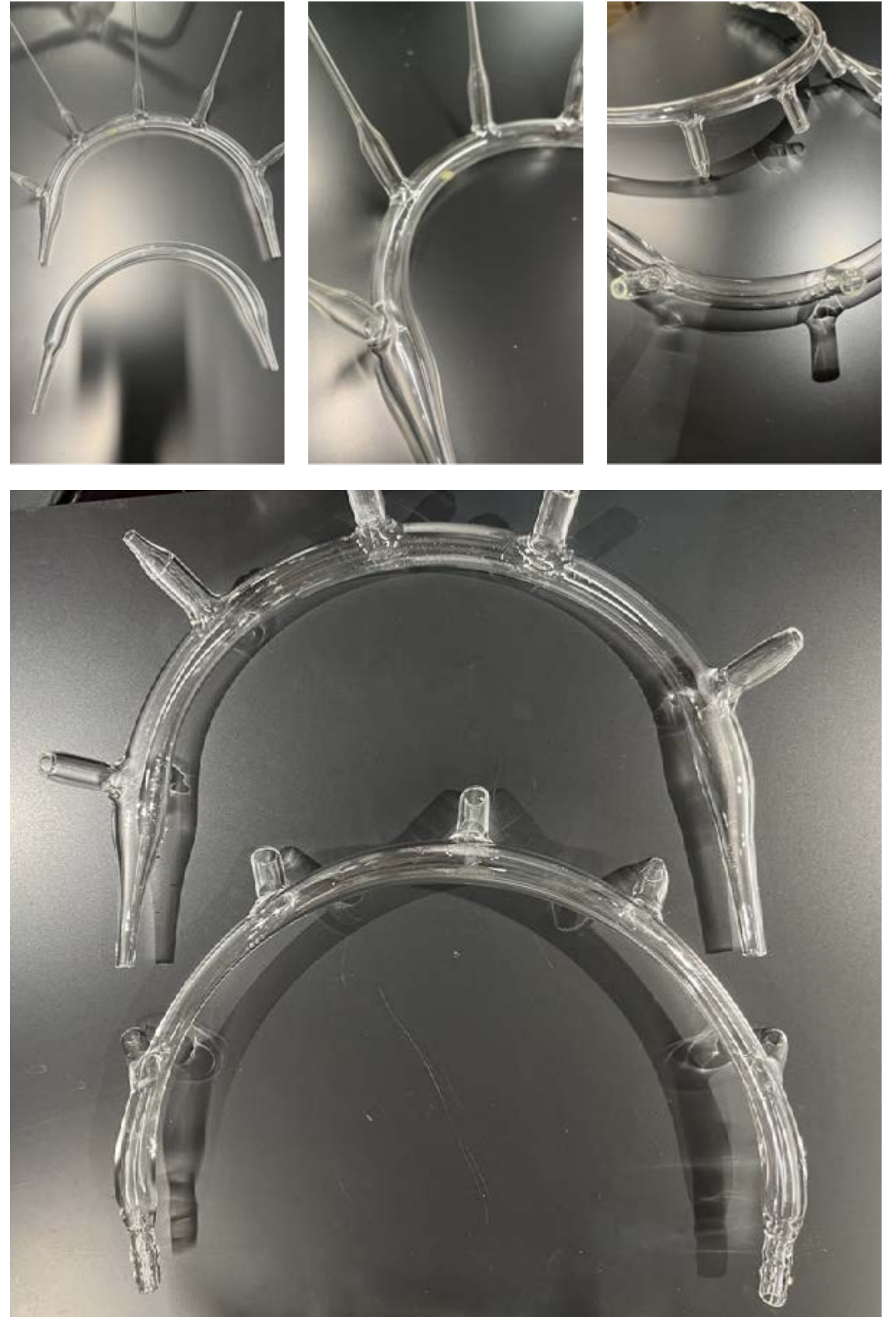
TORSO DEVELOPMENT



PULLED BUBBLE JOINT + CONSTRUCTION



SIDE PANELS + CURVED JOINTS



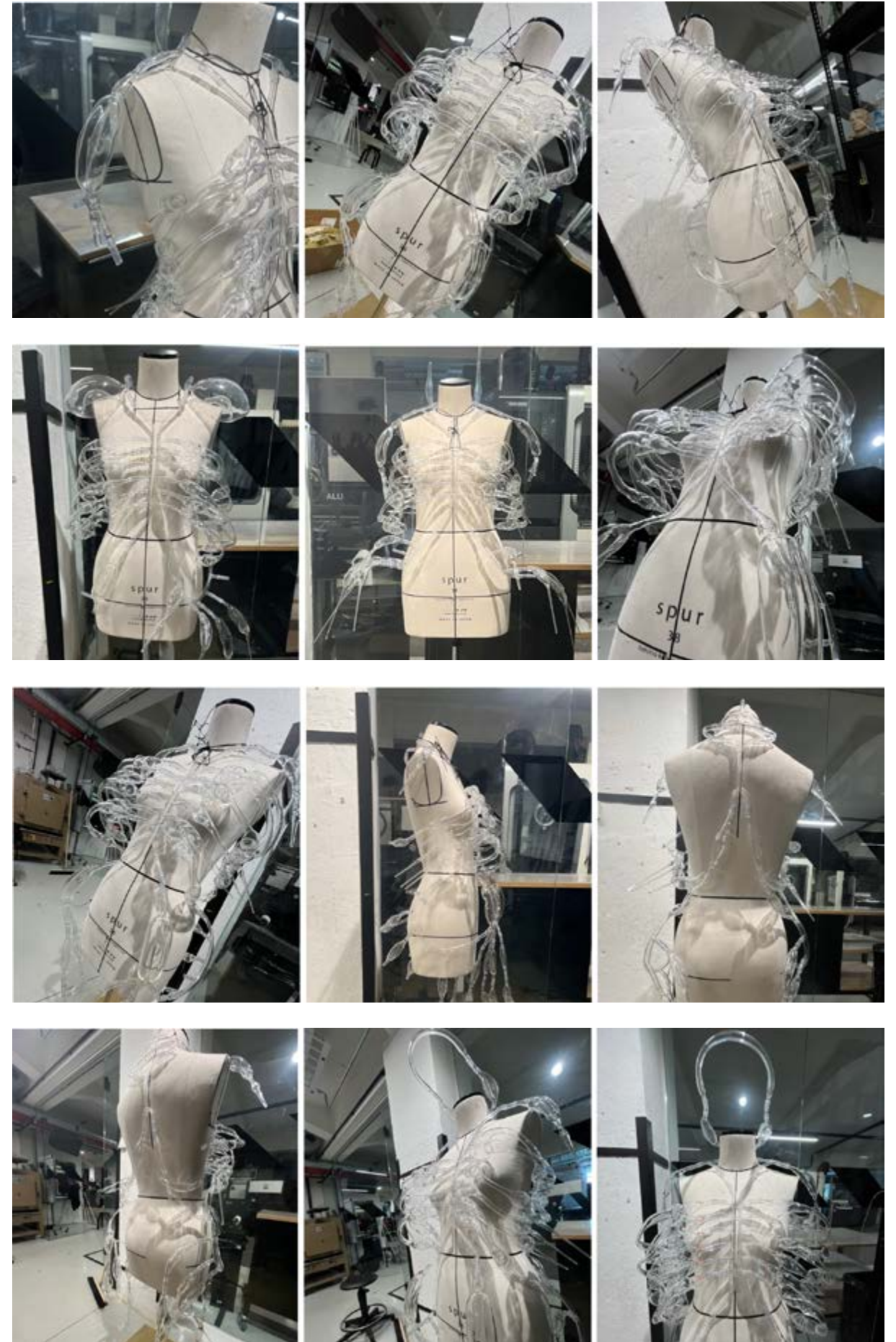
PULLED BUBBLE JOINT + CONSTRUCTION



CONSTRUCTION + SYMMETRICAL ORGANIC BUBBLE EXPLORATION



PLACEMENT TEST



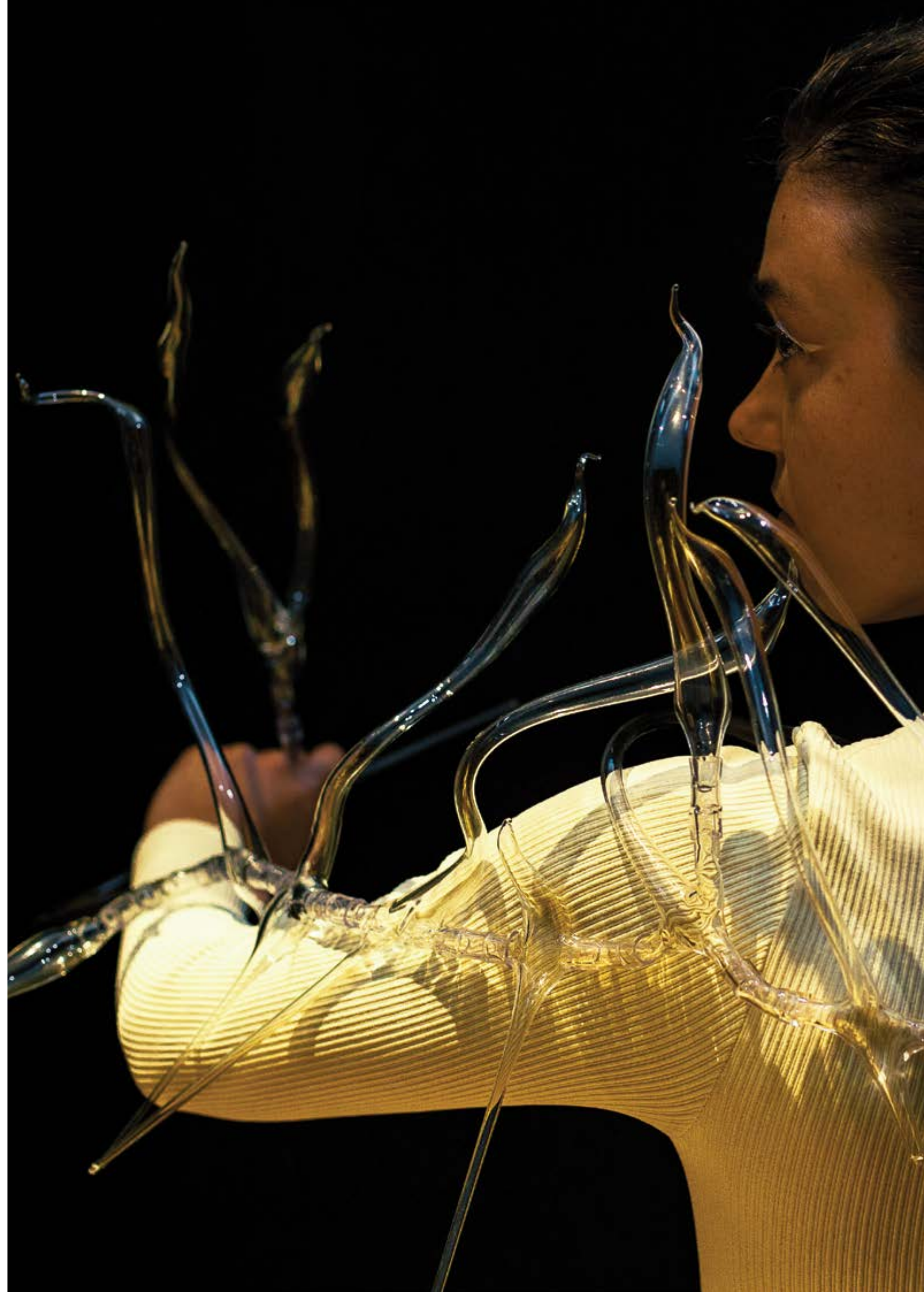




ZONUZ



Zonuz is the most wearable and flexible instrument as it resembles the rotation and movement of the vertebra in the spine. It creates a focus on repetition while emphasizing the expansive qualities of our bodies, and ultimately our breath.





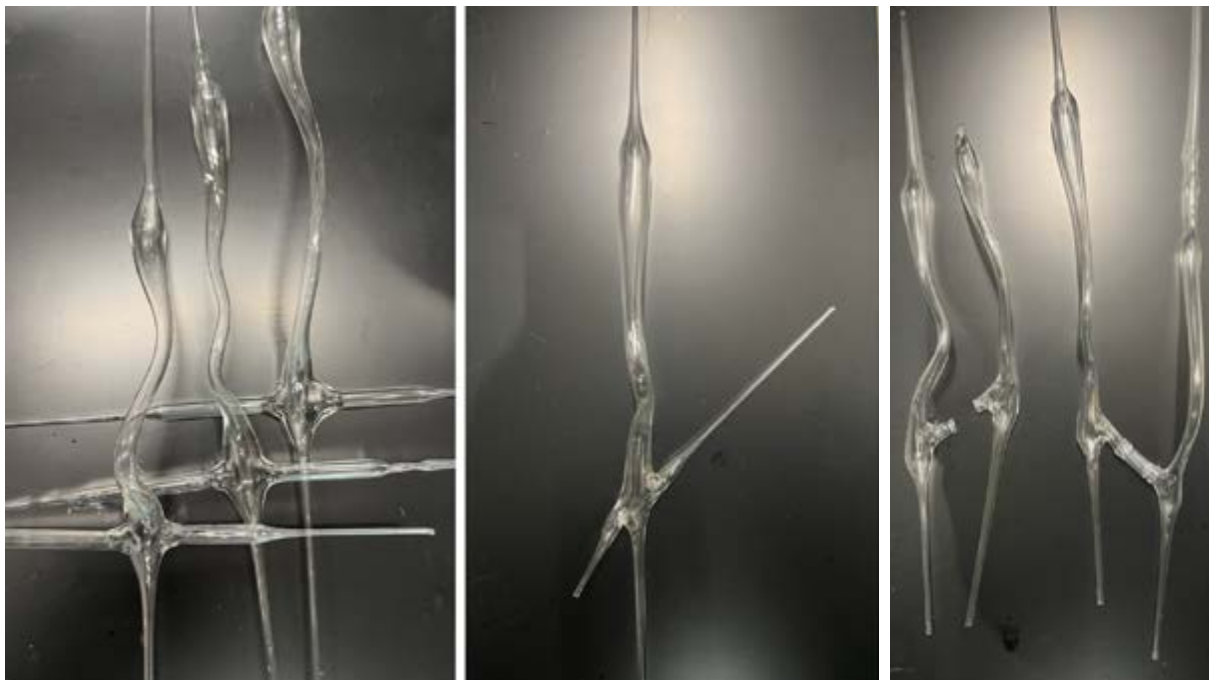
CURVING & REPETITION EXPLORATION



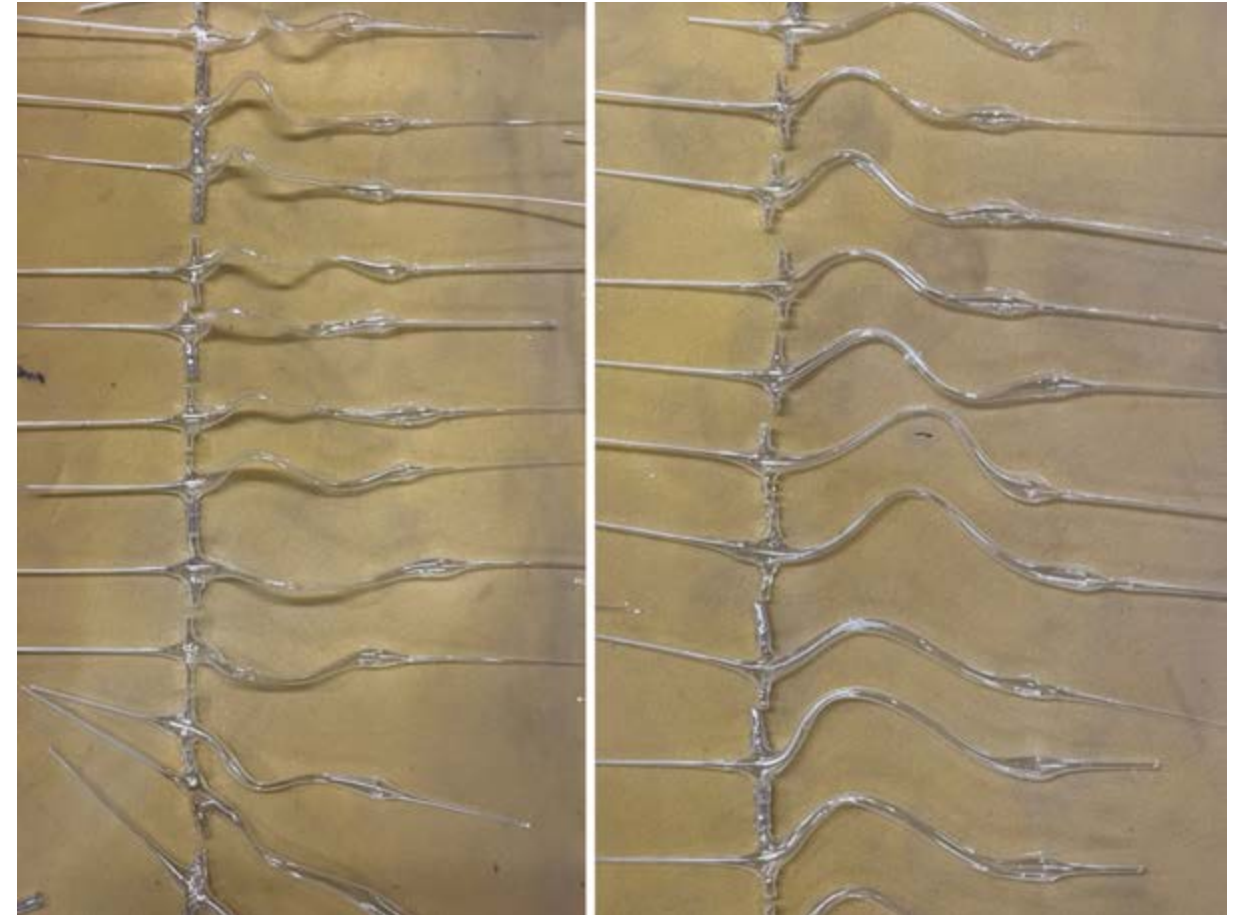
JOINT EXPLORATION



JOINT DIRECTION EXPLORATION



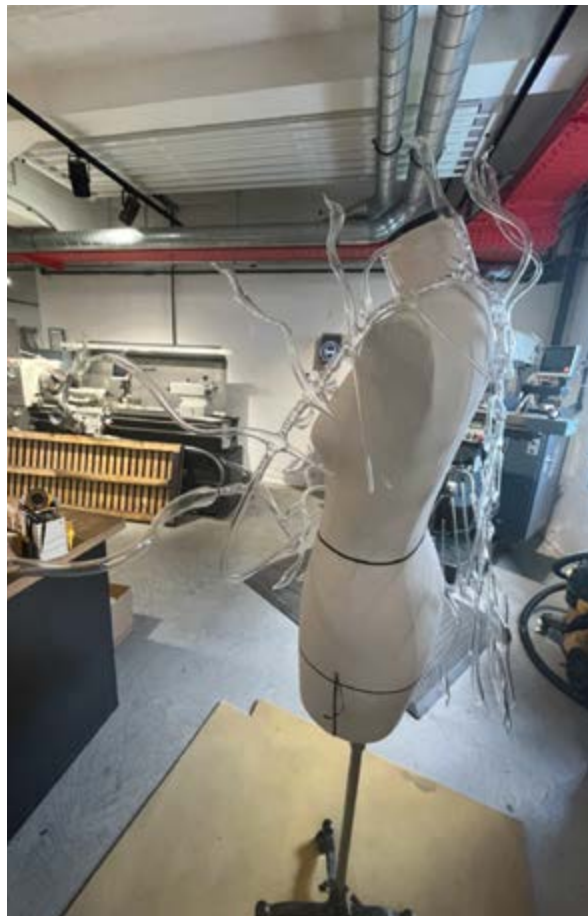
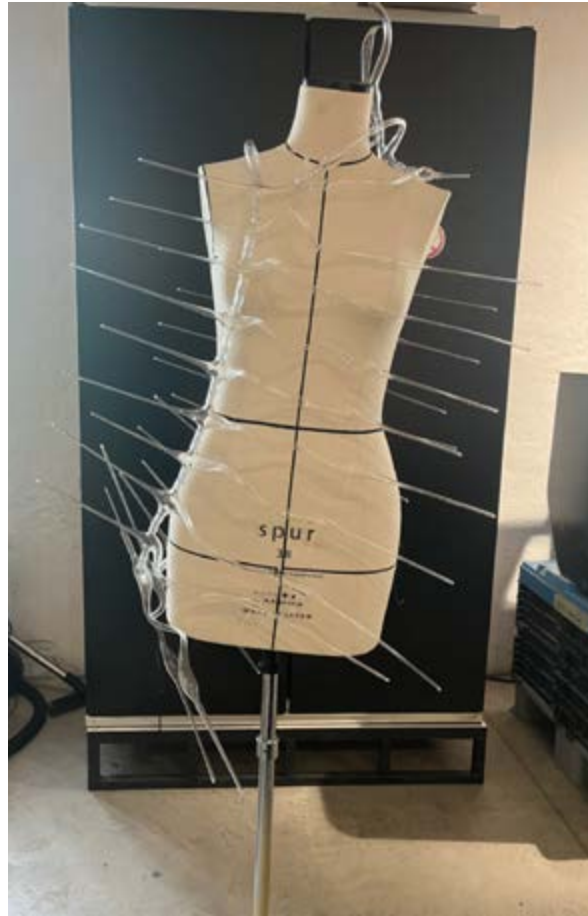
ARRANGEMENT EXPLORATION FOR FLEXIBLE JOINTS



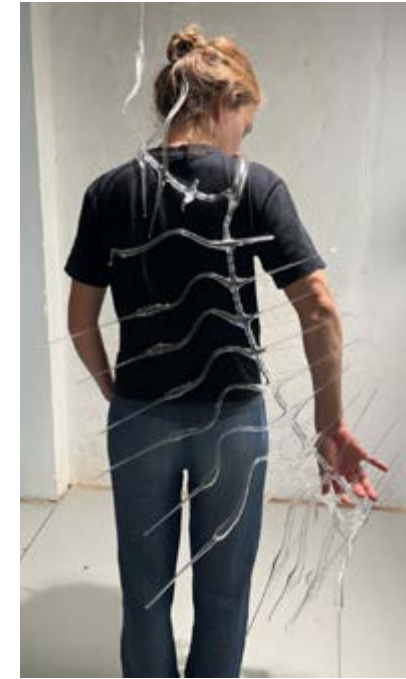
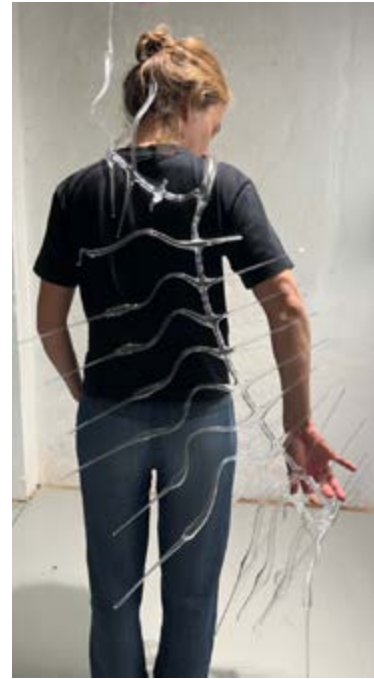
MODULAR CONSTRUCTION PROCESS



DRAPE EXPLORATION



FIT & MOVEMENT EXPLORATION





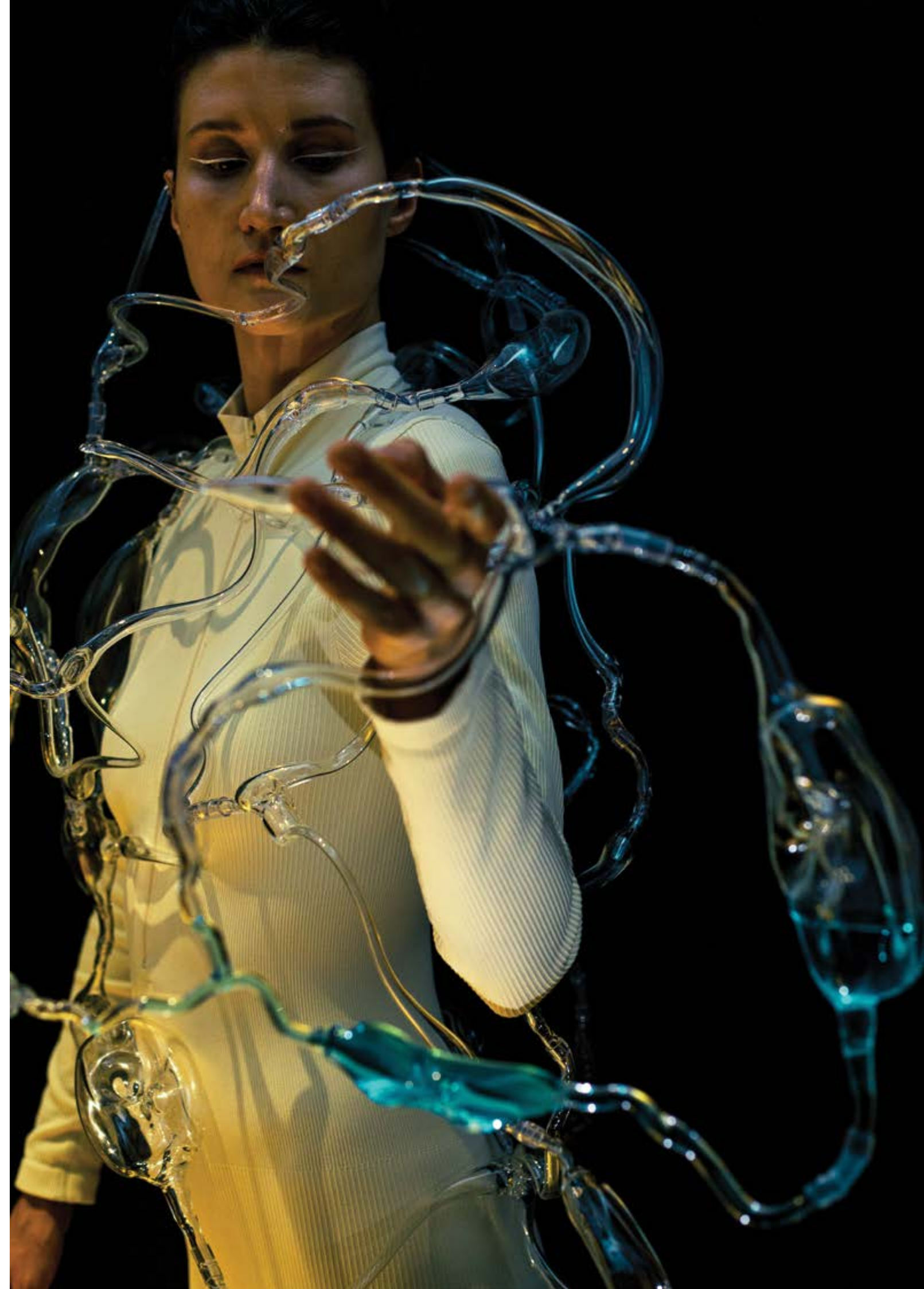
ZPIRITUZ



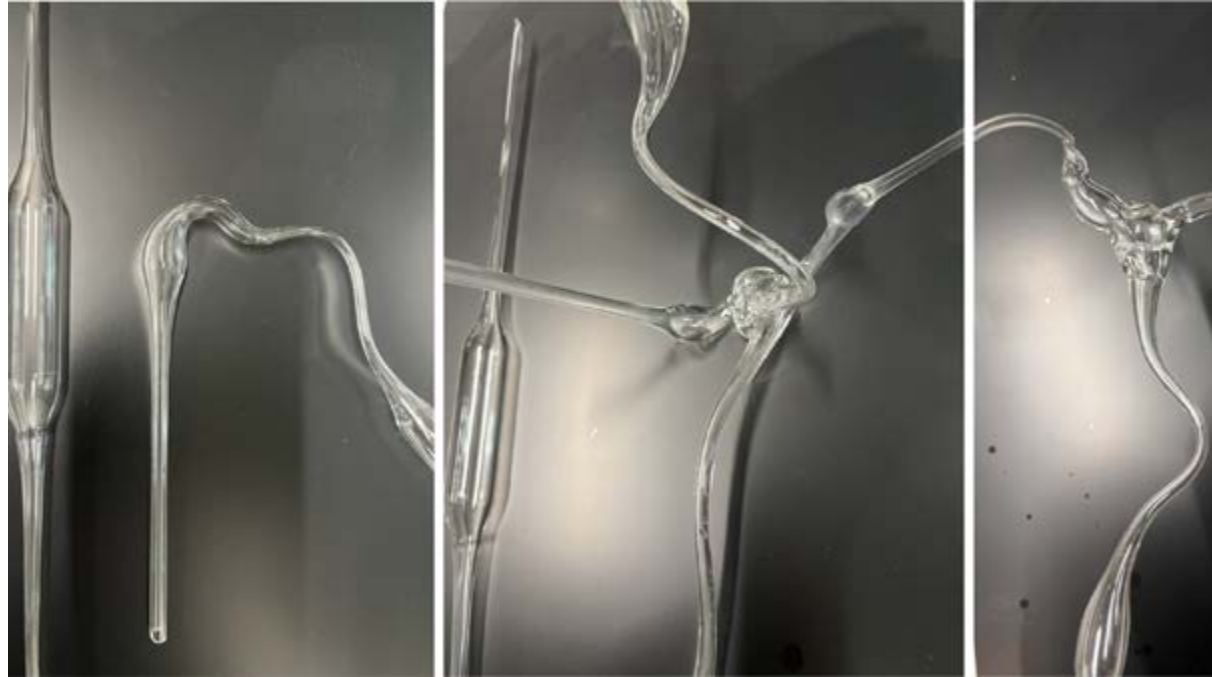
Breathing not only triggers our body through movement, but it is closely connected to our nervous system. This highlights the connection between the power of conscious breathing bringing the nervous system inside out.

Zpirituz's entire structure is hollow and connected all throughout, with one section that is filled with liquid.

The "Breath Bag" is a speculative accessory design of a hand bag, representing what it would be like to carry one's breath.



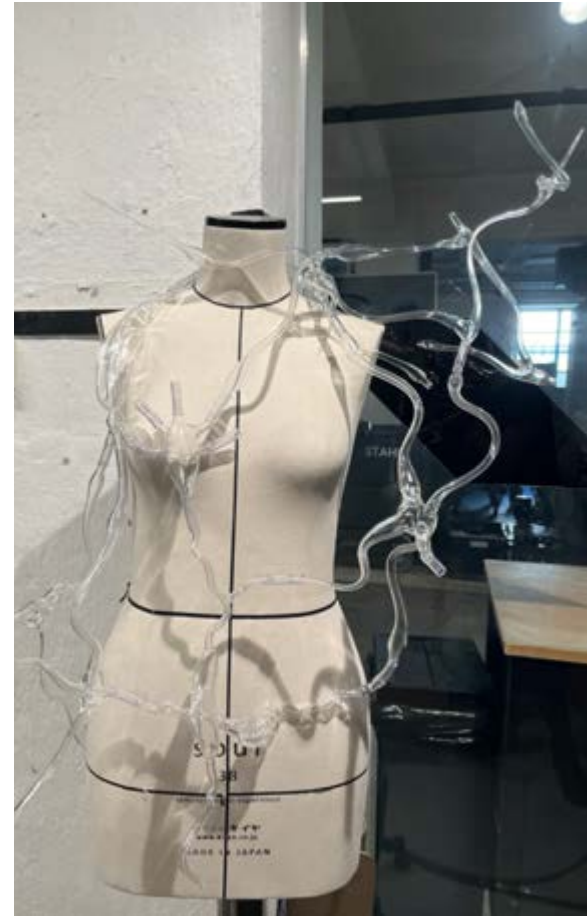
CURVING + JOINING EXPLORATION



CURVES + BUBBLE SHAPE EXPLORATION



PLACEMENT + CONNECTION EXPLORATION







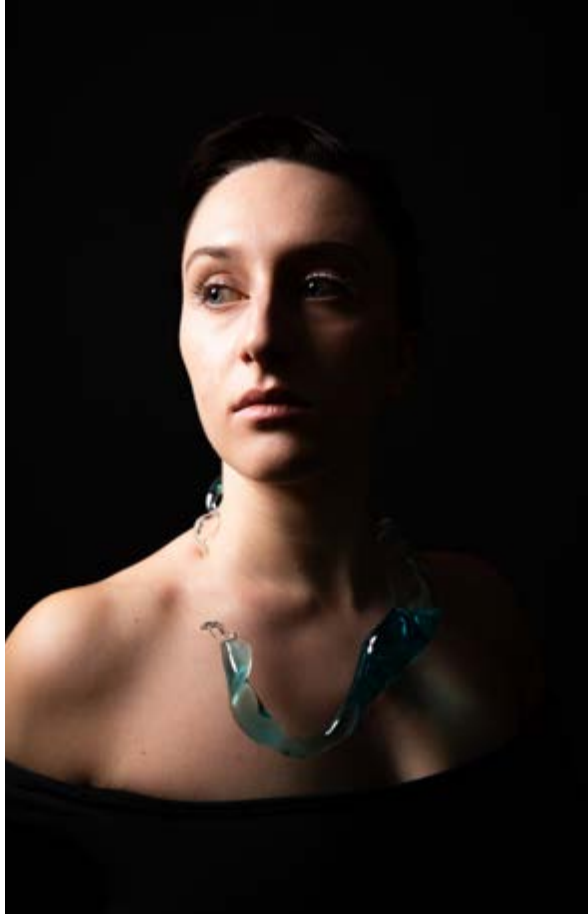
This approach aims to amplify
CRAFTSMANSHIP
as an ART of our FUTURE,
and **BREATHING**
as a TECHNOLOGY of our PRESENT.



The journey of collaboration between Günthe Mausz and the dancers that performed during the Fashion Technology fashion show in Vienna on June 28th, 2024, was a milestone for this project.

This moment marked a transition between ideation to implementation, proving the various possibilities that could be further explored, when the power of working together towards a common goal is achieved.

ZENZ



The exploration process of wearable glass made it clear that the possibility of creating more challenging shapes could be possible. This approach embodied an organic feel for letting breath realize itself without force, but rather flow. As a result, a new working method was discovered that paved the way towards analyzing accessories not only as jewelry, but as moving visualizations and extensions of the body.

As the shadows from previous designs become more highlighted through the testing phase, the idea of adding liquid became increasingly necessary for it to reflect light more vividly. This inspired the design of this glass necklace with no beginning nor end in a contemporary fashion context.



SHADOW/LIGHT ANALYZATION



DEVELOPMENT PROCESS





X. REFLECTION

The lines between the real and unreal become blurred as we move beyond the New Age into the Age of Imagination. With the rapid development in technologies using artificial intelligence, speculative design can be visualized more rapidly than ever before. However, despite the efforts to reproduce and test ideas more efficiently, does Ai truly solve our need for physical materiality? Is it enough to let our ideas live solely in the digital realm?

Our imagination is a tool of endless possibilities - one that can never be replicated as our thoughts may change with unpredictability. As we decode the future of our generations and our present, this thesis seeks to unveil the importance of merging Ai and craftsmanship alongside breathing technology - not only to sustain life, but to create and communicate with life.

After almost two years of experimenting with scientific glass-blowing, new designs were materialized within one to two hours, from first ideation to final production. A process that would have originally taken weeks or months, including hours of 3D manipulation, to 3D-printing and material testing, resulted in minutes with scientific glass-blowing methods. This was a turning point in this artistic investigation, showing the importance of craftsmanship for design as well as our collective future.

Craftsmanship and artificial intelligence could potentially allow us to become more understanding of the relationship within ourselves and others, where our inner world mirrors our outer reality - turning reflection into connection. This artistic exploration aims to bridge traditional handcrafting methods, design, and technology, by highlighting the value of craftsmanship and breathing techniques that allow artists to transform artificially generated designs into physical art through sustainable materials such as glass.



AI

MIDJOURNEY GENERATED IMAGE

PULMONAUT



XI. CONTRIBUTION

Pulmonaut combines layers of ideas that appear disparate but aim to achieve juxtaposition through design, craftsmanship and breathing as a technology. The experimental stage created a variety of possible outcomes, but could only be targeted after a long learning process - with the material and craftsman and designer alike. The synergy explored throughout this artistic approach brings forward the power of co-creation by collaborating with Günther Mausz and working towards innovation and sustainability.

Glass, an everyday material that was seen as simple and at times mundane, became the foundational power that visualized breathing as a shaping tool and an inner technology that we all have access to. This approach brings forward the strength of collaboration between artists, scientists, and craftsmen, while highlighting the importance of the ancient tradition of glass-blowing and the artistic magic it adds to our modern world. Glass eye prosthetics is one of many examples that emphasize the co-creative expertise of surgeons, anatomists, and artisans (Bigotti, F. (2021). Similarly, endeavors like Project Silica by Microsoft and Warner Brothers, focus on the technical aspects of glass to harness its capabilities as a data storage device (Langston, J., 2019). By blending traditional artisanal techniques with cutting-edge technology, innovation arises when diverse fields collaborate. Additionally, glass is 100% recyclable without loss in quality, which further magnifies its life cycle assessment (LCA) and significance in a world increasingly prioritizing eco-conscious practices (Glass Container Recycling Loop, n.d). To co-create with glass is to go beyond the physical norms of the materials and tools. It forces us to evaluate the connection between human touch and technological advancement, and to learn how to community and value mastery in craftsmanship and its role in finding new layers of artistic expression.

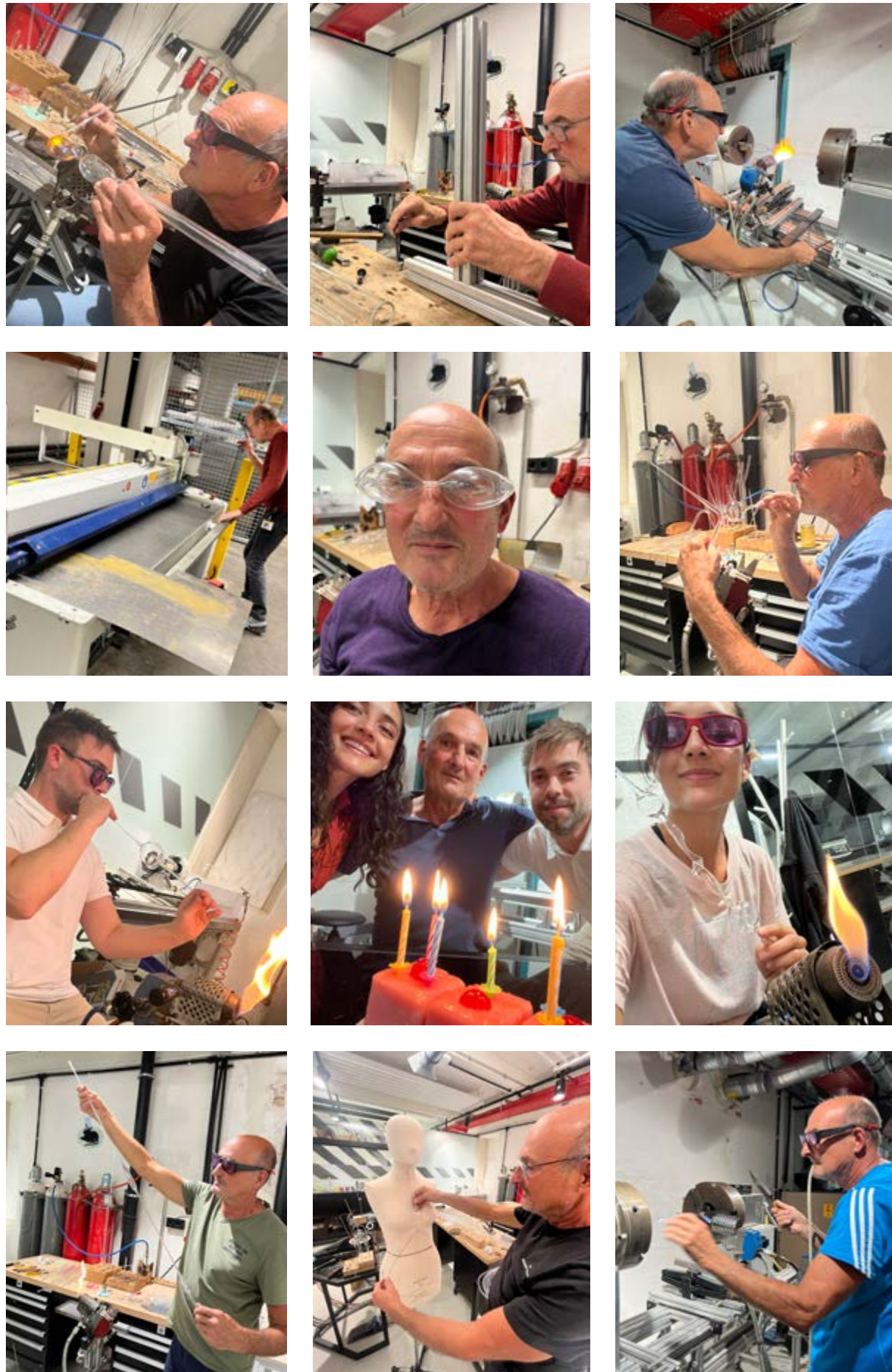
Throughout the development of this project, the constant patience and support received from Günther Mausz enabled the ability to transcend beyond traditional glass-blowing learning and/or teaching methods. The synergy that was achieved became a reflection of efficient design and development processes that can be achieved when people work together. Martin Schwab, from the Creative Robotics department, was also an influential part of this collaborative approach. His remarks on the shared skills and learning journey in relation to the technology and engineering behind this project, offered new view points that enabled a creative solution based approach, highlighting the value of collaboration within different backgrounds.

Pulmonaut emphasizes the strength of breathing techniques by visualizing it's language of creation and co-creating. This artistic practice frames breath as the center point of growth and investigates traditional glass blowing methods while integrating innovation in a sculptural fashion context; enhancing mindful movement and conscious breathing with a collective effort.

As “astronauts explore the depths of space, **PULMONAUTS** explore the depths of their breath.”

- Toth, J., 2023

This approach aims to amplify craftsmanship as an art of our future, and breathing as a universal language and technology of our present.



XII. REFERENCES

Aging changes in body shape: Medlineplus medical encyclopedia (no date) MedlinePlus. U.S. National Library of Medicine. Available at: <https://medlineplus.gov/ency/article/003998.htm> (Accessed: April 10, 2023).

Bernd Weinmayer (2022) PLASMA ART ALLIANCE . Available at: <https://plasmaartalliance.com/members/bernd-weinmayer/> (Accessed: 07 November 2023).

Bigotti, F. (2021) The Making of Early Modern Eye Models, Research Gate. Available at: https://www.researchgate.net/publication/375662752_The_making_of_early_modern_eye_models (Accessed: 20 November 2023).

Brill, R. H. and The Corning Museum of Glass (1977) Glassmakers Of Herat. The Corning Museum of Glass. Available at: <https://www.youtube.com/watch?v=BMYE83DJU4Q> (Accessed: 23 November 2023).

Collin, M. et al. (2018) Structure of international SimpleGlass and Properties of Passivating Layer Formed in Circumneutral pH conditions, Nature News. Available at: <https://www.nature.com/articles/s41529-017-0025-y> (Accessed: 23 November 2023).

Corning Museum of Glass (no date) All About Glass, The Origins of Glassmaking | Corning Museum of Glass. Available at: <https://www.cmog.org/article/origins-glassmaking> (Accessed: 20 November 2023).

Couto Rosado, L. (no date) Telepathy, Laura Couto Rosado. Available at: <https://www.lcr.digital/work/telepathy> (Accessed: 07 January 2024).

Cronkleton, E. (2020) Walking meditation's 10 benefits for mood, sleep & more, Healthline. Healthline Media. Available at: <https://www.healthline.com/health/walking-meditation> (Accessed: March 17, 2023).

Dalladay-Simpson, J. (2022) Reshaping futures: 4 : Designing Personal Practices of World-Making, Taylor & Francis. Taylor & Francis. Available at: <https://www.taylorfrancis.com/chapters/edit/10.4324/9781003205371-4/reshaping-futures-jordan-dalladay-simpson> (Accessed: March 14, 2023).

Den Besten, L. (no date) The jewelry of Gijs Bakker - Ganoksin jewelry making community, Ganoksin. Available at: <https://www.ganoksin.com/article/jewelry-gijs-bakker/> (Accessed: 07 November 2023).

Emard, Justine. (2020) Supraorganism, Light Art Museum Budapest. Available at: <https://lam.xyz/artists/justine-emard/> (Accessed: 22 November 2023).

Fitzgerald, S. (2021) Forest bathing: What it is and where to do it, National Geographic. National Geographic. Available at: <https://www.nationalgeographic.com/travel/article/forest-bathing-nature-walk-health#:~:text=The%20term%20emerged%20in%20Japan,and%20protect%20the%20country's%20forests.> (Accessed: March 17, 2023).

Glass Container Recycling Loop (no date) Glass Recycling Facts - Glass Packaging Institute. Available at: <https://www.gpi.org/glass-recycling-facts#:~:text=Glass%20Facts-,Glass%20is%20100%25%20recyclable%20and%20can%20be%20recycled%20endlessly%20without,than%20the%20cullet%20is%20sand.> (Accessed: 09 November 2023).

Guo, C. (2010) The Development of Chinese Glass Buildings, Proceedings Challenging Glass. Available at: <https://proceedings.challengingglass.com/index.php/cg/article/view/10/10> (Accessed: 23 November 2023).

Haraway, D. (2003) 'The Companion Species Manifesto: Dogs, People, and Significant Otherness'. Chicago: Prickly Paradigm Press.

Highlike.org (no date) Naomi Filmer, highlike. Available at: <https://highlike.org/text/naomi-filmer-3/> (Accessed: 2023).

Human: The World Within (2021) [Docuseries, Investigative] Directed by Jad Abumrad. United States. PBS.

Hu1, X.-S. et al. (2021) Brain mechanisms of virtual reality breathing versus traditional mindful breathing in pain modulation: Observational functional near-infrared spectroscopy study, *Journal of Medical Internet Research*. JMIR Publications Inc., Toronto, Canada. Available at: <https://www.jmir.org/2021/10/e27298/#ref> (Accessed: March 16, 2023).

If the Glass Fits (no date) Corning. Available at: <https://www.corning.com/worldwide/en/innovation/the-glass-age/inspiration/if-the-glass-fits.html> (Accessed: 07 November 2023).

Invention in Early Glassblowing - The Road to Ennion with Bill Gudenrath | Behind the Glass Lecture (2015). Corning Museum of Glass. 27 February. Available at: <https://www.youtube.com/watch?v=0iHEQTc-tY4E> (Accessed: 23 November 2023).

Kelp, Z. (no date) Pneumacosm, Zamp Kelp. Available at: <https://www.zamp-kelp.com/pneumacosm/> (Accessed: 07 November 2023).

Kooroshnia, Marjan. (2013) Dream Vase, Swedish School of Textiles. Available at: <https://hb.diva-portal.org/smash/get/diva2:884795/FULLTEXT01.pdf> (Accessed: 23 November 2023).

Kochan, A. (1997) 'CyberGlass - glass-blowing Robot'. *Industrial Robot: An International Journal*.
Langston, J. (2019) Project Silica Proof of Concept Stores Warner Bros. 'Superman' movie on Quartz Glass, Microsoft. Available at: <https://news.microsoft.com/source/features/innovation/ignite-project-silica-superman/#:~:text=A%20laser%20encodes%20data%20in,light%20shines%20through%20the%20glass.> (Accessed: 09 November 2023).

LePinnet, P. (no date) Laboratory scientific glassblowing: Advanced Techniques and glassblowing's place in history, Google Books. Available at: https://books.google.at/books?hl=en&lr=&id=YQhqEAAAQ-BAJ&oi=fnd&pg=PR7&dq=scientific%2Bglass%2Bblowing%2Bfor%2Bfashion%2B&ots=cBKXy1jaxB&sig=DI-JEFJB3pZEhMgfUf7jw0A2gcYg&redir_esc=y#v=onepage&q&f=false (Accessed: 23 November 2023).

Lewis, M. (2021) Glass Eye Making, Heritage Crafts - Red List of Endangered Crafts. Available at: <https://heritagecrafts.org.uk/glass-eye-making/> (Accessed: 23 November 2023).

Machlich, H. (2022) Iris van Herpen on creating her glass 'dimensionism' dress, SHOWstudio. Available at: <https://showstudio.com/news/iris-van-herpen-on-creating-her-glass-dimensionism-dress> (Accessed: 23 November 2023).

Mather, M. and Thayer, J. (2018) How Heart Rate Variability Affects Emotion Regulation Brain Networks, National Center for Biotechnology Information. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5761738/> (Accessed: 23 November 2023).

M. -C. Yu, H. Wu, M. -S. Lee and Y. -P. Hung, "Multimedia-Assisted Breathwalk-Aware System," in *IEEE Transactions on Biomedical Engineering*, vol. 59, no. 12, pp. 3276-3282, Dec. 2012, doi: 10.1109/TBME.2012.2208747.

National Geographic Society. "Anthropocene", May 20, 2022, accessed January 9, 2023, <https://education.nationalgeographic.org/resource/anthropocene>

O'Connor, E. (2007) 'Embodied knowledge in glassblowing: the experience of meaning and the struggle towards proficiency'. The Editorial Board of the *Sociological Review*.

Petersen, A. (2018) Industrial Robots for Glass Manufacturers, IPG Genesis Systems. Available at: <https://www.genesis-systems.com/blog/industrial-robots-glass-manufacturers> (Accessed: 09 November 2023).

Poole, L. et al. (1951) *The Johns Hopkins Science Review - The Master Glass Blower*. Baltimore, MD: Du Mont. Available at: <https://www.youtube.com/watch?v=r9GSMa2IF2A> (Accessed: 11 November 2023).

Prasad, Dr.R. and RK, S. (2023) Ocular Prosthesis: A Next Generation Cosmetic Management by an Eye for an Eye. Available at: <https://austinpublishinggroup.com/ophthalmology-visual-sciences/fulltext/jovs-v8-id1077.pdf> (Accessed: 23 November 2023).

P. -Y. Hwang, C. -C. Chou, W. -C. Fang and C. -M. Hwang, "Smart shoes design with embedded monitoring electronics system for healthcare and fitness applications," 2016 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW), Nantou, Taiwan, 2016, pp. 1-2, doi: 10.1109/ICCE-TW.2016.7520983.

Rebovich, K. (2017) The infant incubator in Europe (1860-1890), *The Infant Incubator in Europe (1860-1890) | Embryo Project Encyclopedia*. Available at: <https://embryo.asu.edu/pages/infant-incubator-europe-1860-1890#:~:text=That%20incubator%20could%20hold%20up,heat%20and%20warm%20the%20infants> (Accessed: 23 November 2023).

Robotics and Automation for the Glass Industry (no date) ADBrobot. Available at: <https://www.adbrobot.com/en/robotics-and-automation-solutions-for-industry-4-0/robotics-and-automation-for-glass-industry/> (Accessed: 09 November 2023).

Robyn (2010) Indestructible, Wikipedia. Available at: [https://en.wikipedia.org/wiki/Indestructible_\(Robyn_song\)#:~:text=The%20dress%20for%20the%20video,flowing%20was%20%22very%20complicated%22.](https://en.wikipedia.org/wiki/Indestructible_(Robyn_song)#:~:text=The%20dress%20for%20the%20video,flowing%20was%20%22very%20complicated%22.) (Accessed: 07 February 2024).

CS. Tivatansakul and M. Ohkura, "Healthcare System Focusing on Emotional Aspects Using Augmented Reality - Implementation of Breathing Control Application in Relaxation Service," 2013 International Conference on Biometrics and Kansei Engineering, Tokyo, Japan, 2013, pp. 218-222, doi: 10.1109/ICBAKE.2013.43.

Statistics & Facts (2023) Global Wellness Institute. Available at: <https://globalwellnessinstitute.org/press-room/statistics-and-facts/> (Accessed: March 15, 2023).

Sukel, K. (2019) Understanding the power of meditation, BrainFacts.org. Available at: <https://www.brainfacts.org/thinking-sensing-and-behaving/thinking-and-awareness/2019/understanding-the-power-of-meditation-041919> (Accessed: March 17, 2023).

Toth, J., "Getting High on My Own Supply: Adventures as a Pulmonaut," 2023 Medium. Available at: <https://somewhatcyclops.medium.com/getting-high-on-my-own-supply-ccc489f77cc5#:~:text=Thus%2C%20a%20pulmonaut%20is%20simply,how%20it%20impacts%20their%20being.> (Accessed: 07 November 2023).

Van Schie, C., Ulbrecht, J.S. and Cavanagh, P.R. (2020) "Design Criteria for Rigid Rocker Shoes." University Park, PA: American Orthopedic Foot & Ankle Society, Inc., Penn State University.

WIRED (2021) Scientific Glass Blower Makes Beer Glasses | Wired, YouTube. Available at: <https://www.youtube.com/watch?v=3cxt8iOPYyY> (Accessed: 09 November 2023).

“ESTARÉ EN EL AIRE.”

- Ligia Harnisth, 18.04.1929 - 09.06.2024



LIALARREA.COM



CC BY-NC-ND 4.0 International
Namensnennung - Nicht-kommerziell - Keine Bearbeitung 4.0 International