Zoomorphic Extended Body

Zoomorphic Extended Body

A thesis presented in partial fulfillment of the requirements for the degree of Masters of Industrial in the Department of Industrial Design of the Rhode Island School of Design, Providence Rhode Island

by

Nicholas Tamas
2021

Approved by Master's Examination Committee:

Signature

____

Agatha Haines, Professor, Industrial Design, Thesis Chair

Signature

____

Soojung Ham, Professor, Industrial Design, Thesis Chair

Signature

____

Yiran Zhao, PhD Researcher, Thesis Advisor,

Special Thanks to

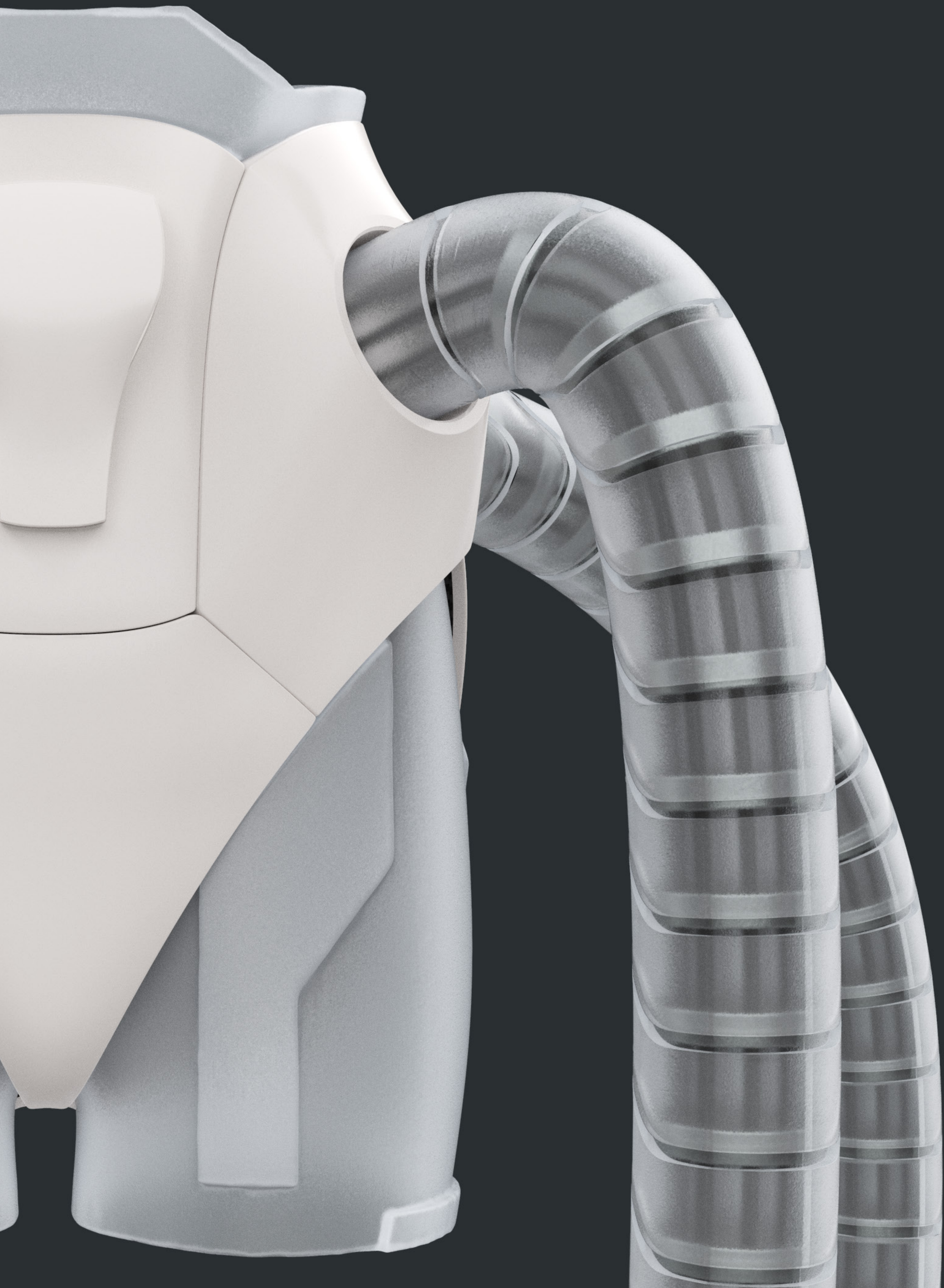
Jingwei Deng

&

Megan Tamás

for their help and support throughout the

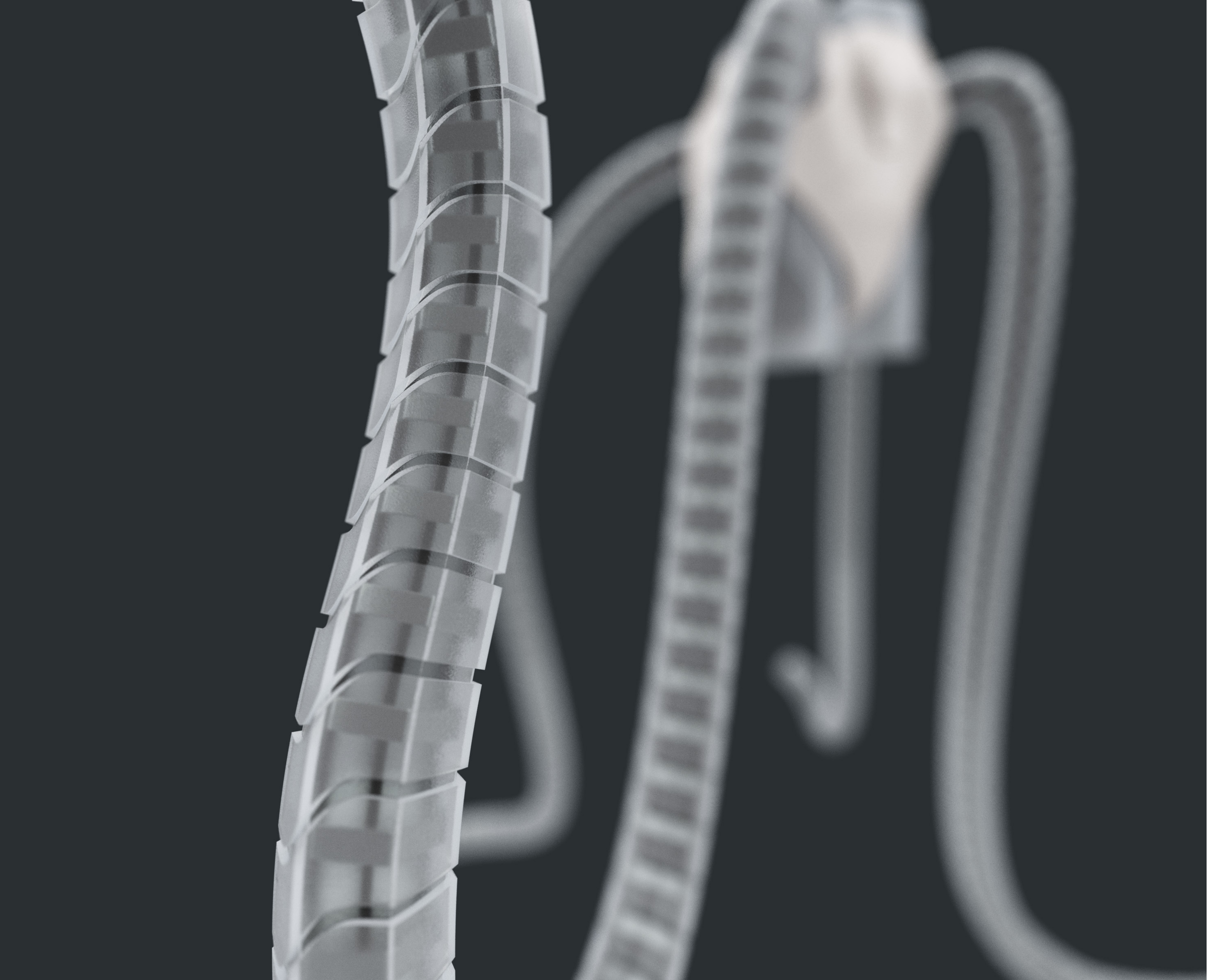
development of this thesis



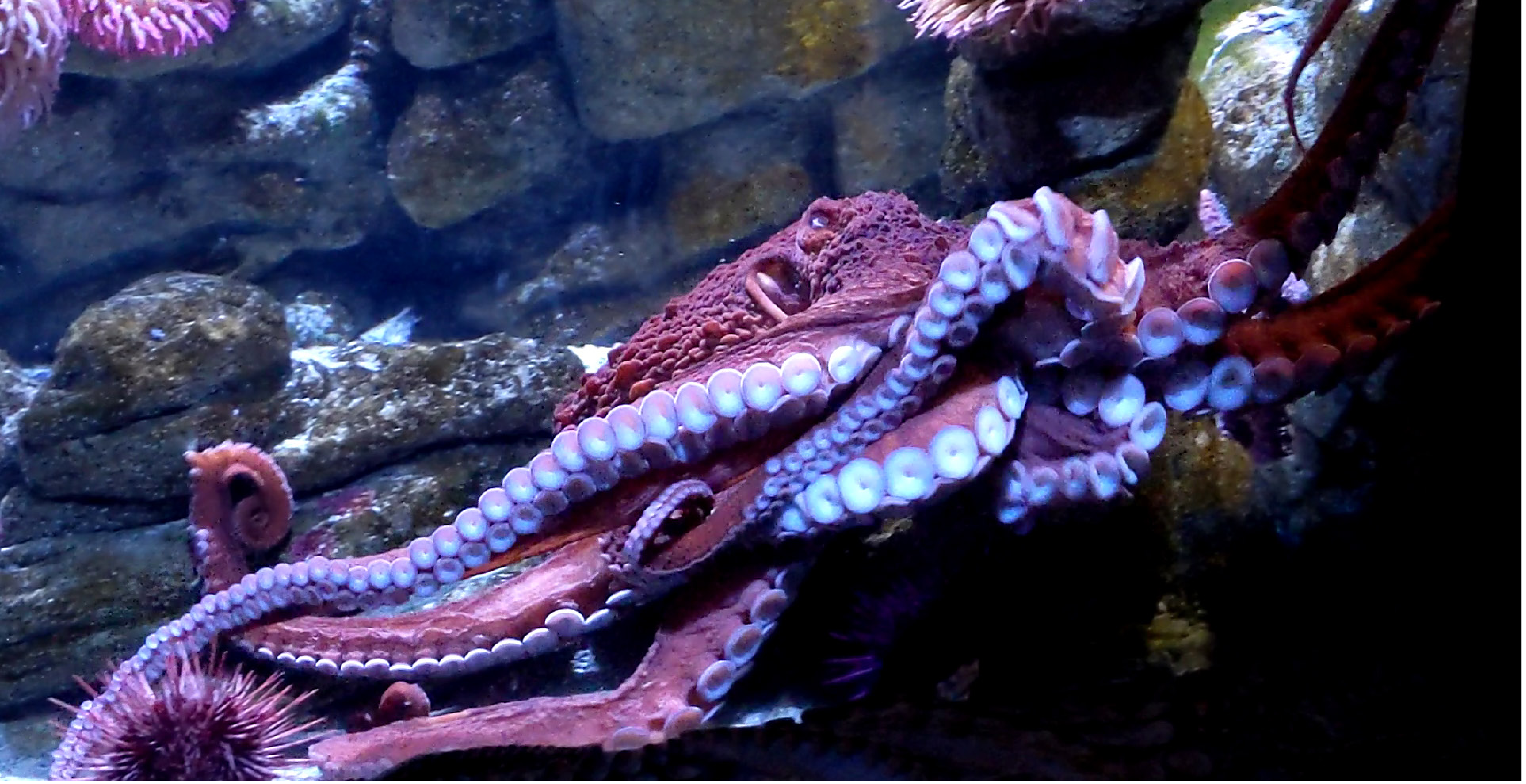
zoomorphic extended body

a speculative design proposal

by nicholas tamás



CONTENTS



PREFACE

When I first saw him, it was on a blog online. I've seen a few like him before, most were from somewhere in Asia, but few were as large as him. I've seen smaller ones, mostly of a different species at the supermarket or at restaurants, but never alive. Maybe it's because I come from an inland state where they are uncommon, or maybe it's the part of the world that I'm from, but I've never seen a live one before. Boston wasn't that far, about an hour away, so I decided to make the trip with my partner to see him. We bought our tickets online and picked them up at the door. The New England Aquarium had many exhibits with a lot of diverse and unique wildlife. Central among the aquarium was a large central cylindrical tank with pools at its base that were populated by different species of penguins, this was the first thing I noticed as I walked in. Around this central feature was a gently sloping ramp that rose upwards in a spiral towards the top floor of the aquarium. Lining this ramp were different exhibits all filled with different aquatic life. Eels, turtles, jellyfish, multiple cephalopods, and an enormous amount of fish; but the one I was looking for and the reason I made the trip was at the very end, and there was a line to see him. Tatuche (pronounced ta-toosh) was a 2 year old, 8 pound giant pacific octopus, and when I first saw him I mistook him for a piece of coral despite his size. Tatuche had a habit of compressing his body into the corner of his tank and then dramatically changing the texture of his skin into spiky tendrils to mimic the surrounding corals and anemones. For long stretches of time he would just sit there slowly breathing, or at least Tatuche's version of breathing. Then, every 15 to 20 minutes or so he would feel the sudden urge to explore his tank. He'd start with one tentacle. You would notice a small tendril slowly drifting out from under him as it snaked and extended its way out from under his body; and then all at once he would unfold like the most nebulous piece of fleshy origami. Watching him glide around the tank as his limbs absently touched, recoiled and wrapped around things was breathtaking to behold. It seemed more complex than I could have imagined, there were so many elements happening simultaneously that video simply does not do it justice. Each limb acting autonomously yet in tandem with the others, while simultaneously the shape, texture, color, and form were all dynamically transforming. I went there to study him but was overwhelmed with what I observed, instead I had to focus my observations to discernable motions that I could replicate: locomotion. I feel like I could do a thesis every year for the rest of my life based on the adaptations from Tatuche alone and each thesis would be completely different, he's truly a remarkable creature.

"the mystery of life isn't a problem to solve, but a reality to experience"

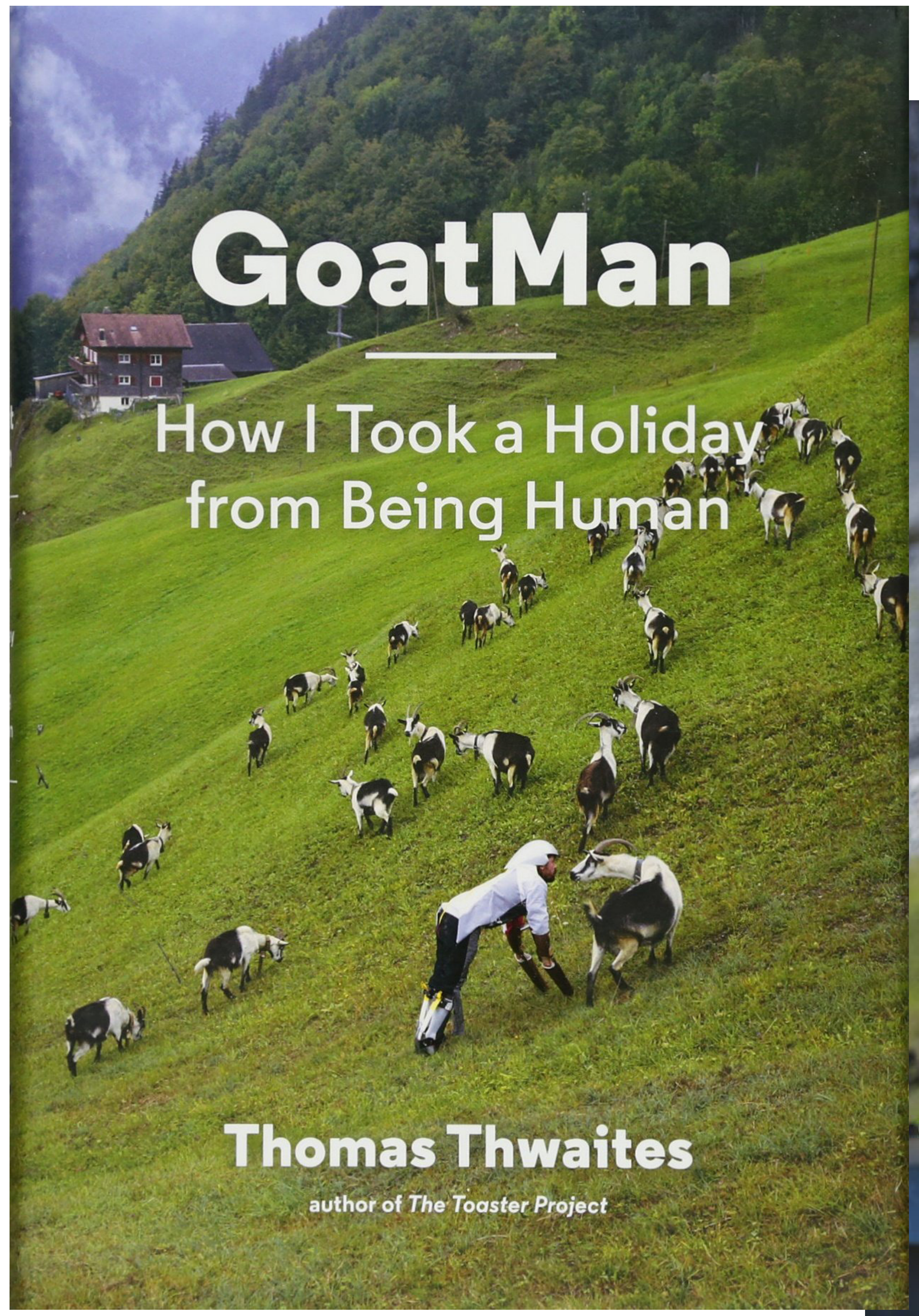
- Frank Herbert, Dune

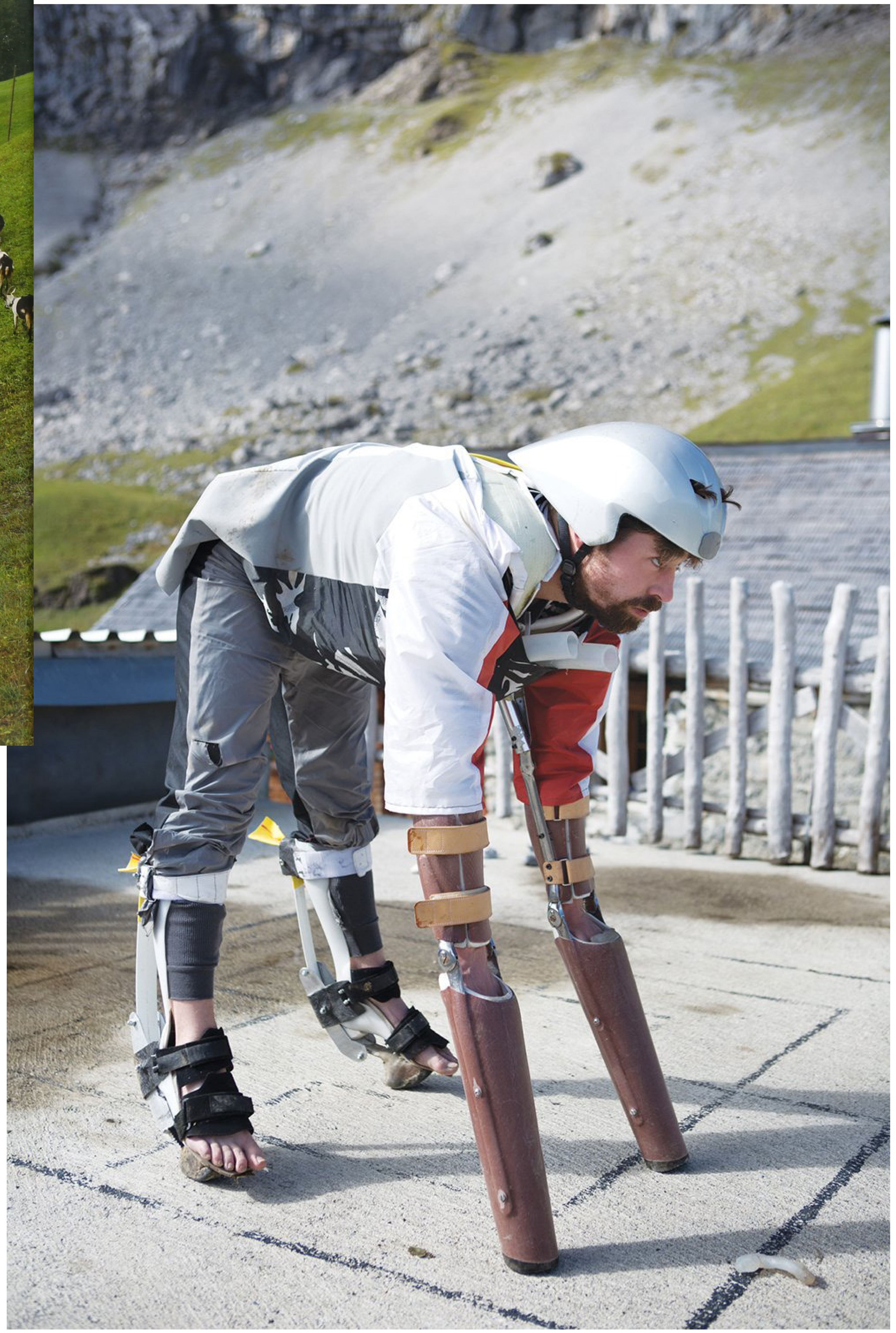
DESIGN SUMMARY

Zoomorphic extended body is a speculative design proposal focused around the application of emerging technologies within the field of neural prosthetics and the use of Brain Computer Interfaces to control mechanical limbs. For Decades the fields of prosthetics, orthotics, and other fields that seek to intersect the human body with mechanical apparatuses have been hampered by numerous design challenges. Many of these poor designs as my following research will show stem from a medical and engineering first approach. The result of this mentality when creating these designs results in the creation of designs that are bulky, cumbersome, and not user friendly or oriented. Furthermore, it results in the creation of designs where the materials composing the designs and the underlying technology supporting those designs are often working at odds with one another. Early in my research I discovered that designs that adapt and apply some of the physical adaptations of animals into their designs rather than simply trying to replicate human forms and functions showed more potential for alleviating some of the underlying problems present within contemporary prosthetic designs. They also showed enormous potential in augmenting and enhancing the abilities of their users past their otherwise normal potential under certain circumstances.

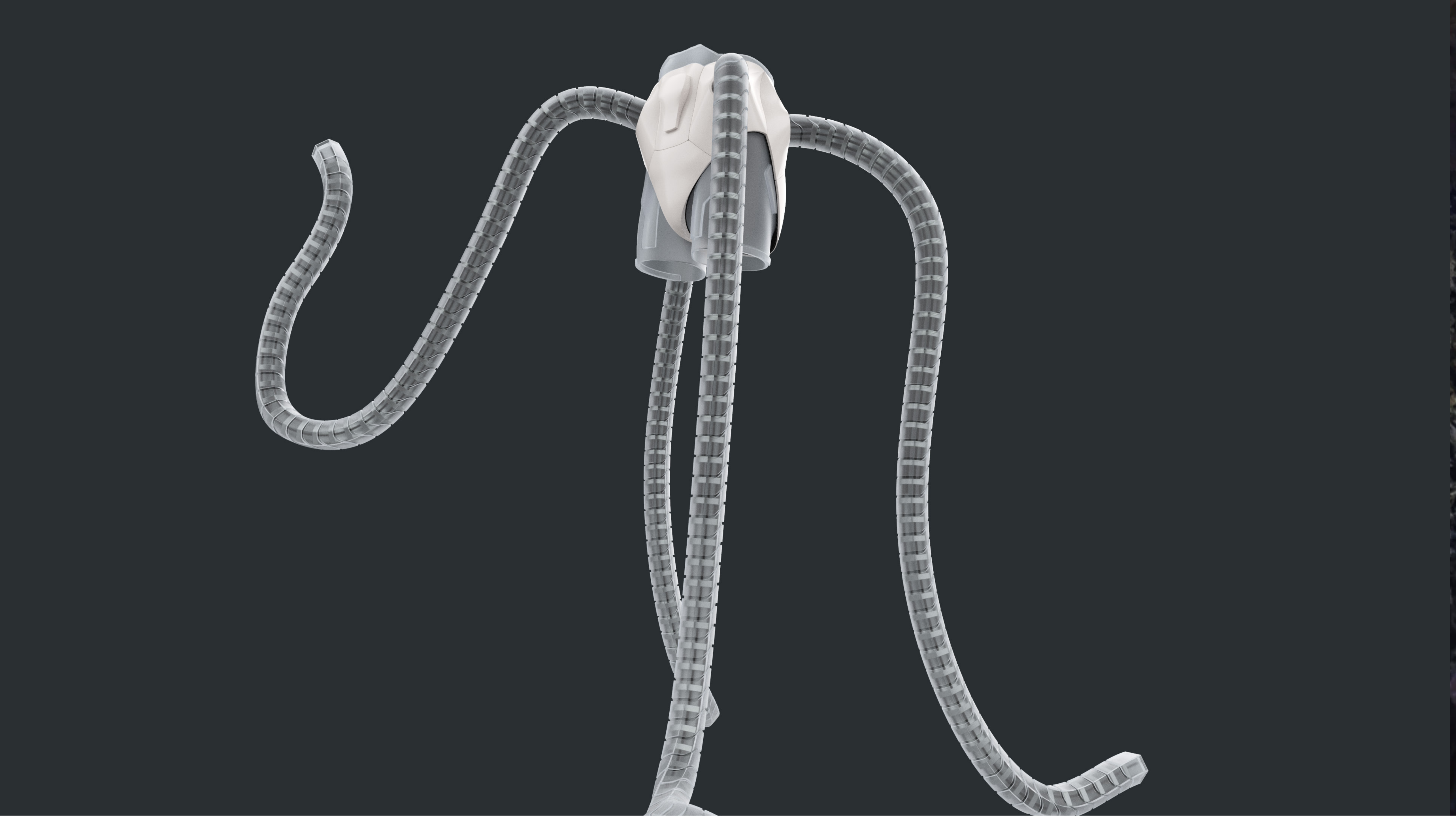
Flamingo Leg Prototype
An early altered body prototype inspired by the physiological adaptations found in the flamingo. This prosthetic would theoretically allow the user to more easily and quickly traverse flooded areas.

But the Zoomorphic Extended Body is not a prosthetic design, it is an extended body design. I will go into more detail later as to why I created and why I am using this term and what exactly it means. But if i had to explain it briefly it would be this: where prosthetic designs seek to replace parts of the body to augment or supplement its behavior, and where orthotic designs seek to work around the body in order to enhance or augment it, extended body designs build off of the body to add new abilities and senses. It is additive, not subtractive. In Thomas Thwaite's 2016 book, Goat Man, there is a section dedicated to exploring the relationship between our human bodies and the technology we create to supplement it. In it, he explains the process used for domesticating goats, the selection and culling of the more aggressive members of their species, resulted in drastic changes to the species as a whole. Calmer less aggressive behavior, smaller brains, and softer features were some of the changes that occurred over time and across generations. He goes on to argue that throughout this process, humans underwent a similar process of domestication amongst ourselves. Citing anthropological research from Richard Wrangham, a professor of biological anthropology at Harvard University, over the past 10 thousand years of human history, the human species has undergone drastic physiological changes, and these changes seem to have corresponded with our own development of technology. Like the goats, our brains have shrunk and measurable aspects like reaction time appear to be slowing with each subsequent generation. Despite this, our overall IQ and ability to problem solve complex theoretical problems and arrive at equally complex solutions appears to be increasing. For all the evidence presented, the start of the Neolithic Age appears to signal the halt in human evolution, and in many ways we have been de-evolving ever since. But how is it that we seem to be getting smarter while our bodies become less and less physically capable? One possible reason, and a reason that Thwaites and Wrangham seem to suggest, is that we have replaced our physical evolution with a technological one. Where once, we might have acquired adaptations over time in order to better cope with our surrounding environment, we now develop technology instead. In this way, our technology is very much an extension of ourselves, and how we choose to develop it reflects how we choose to interact, coexist, or even dominate our environment.

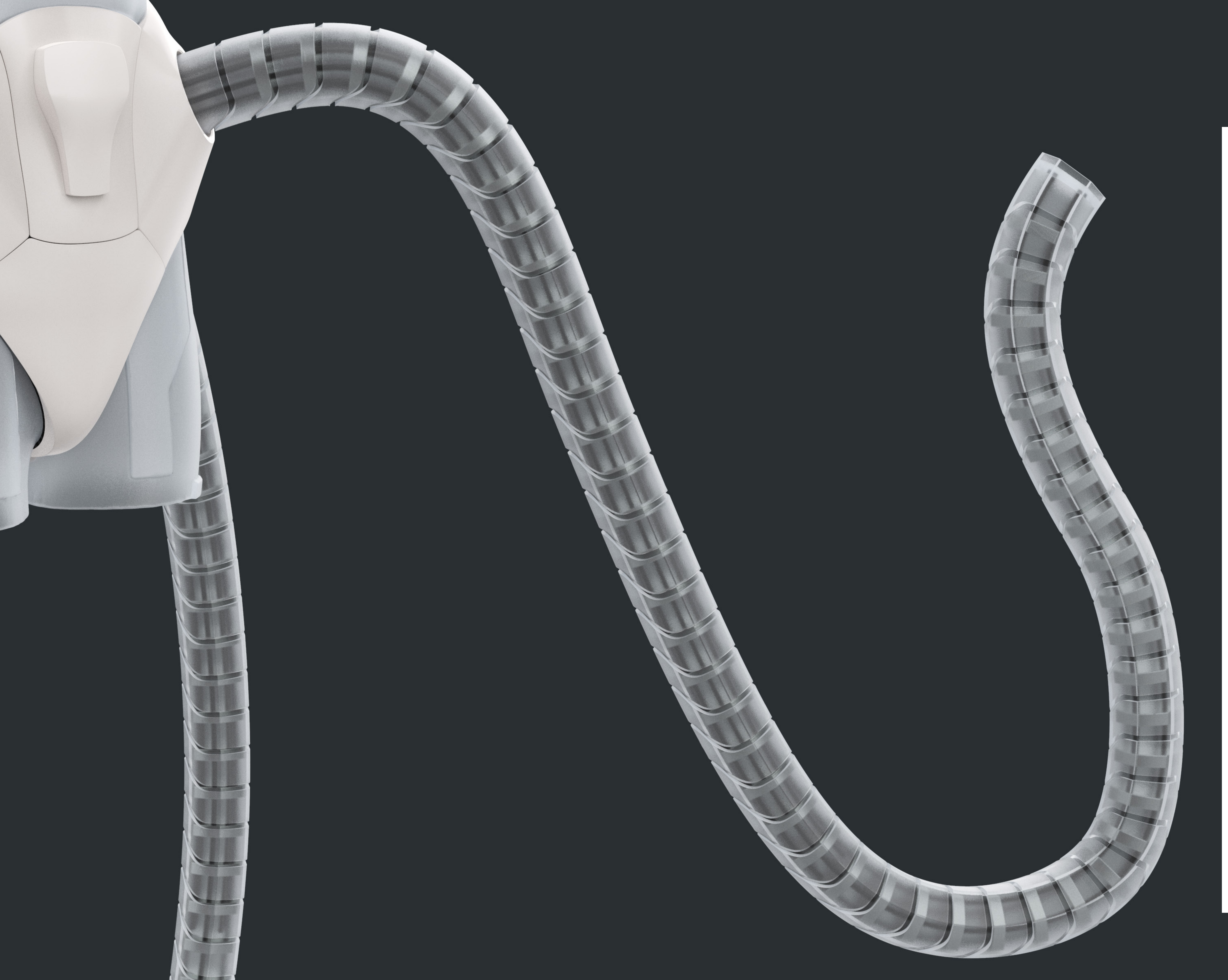




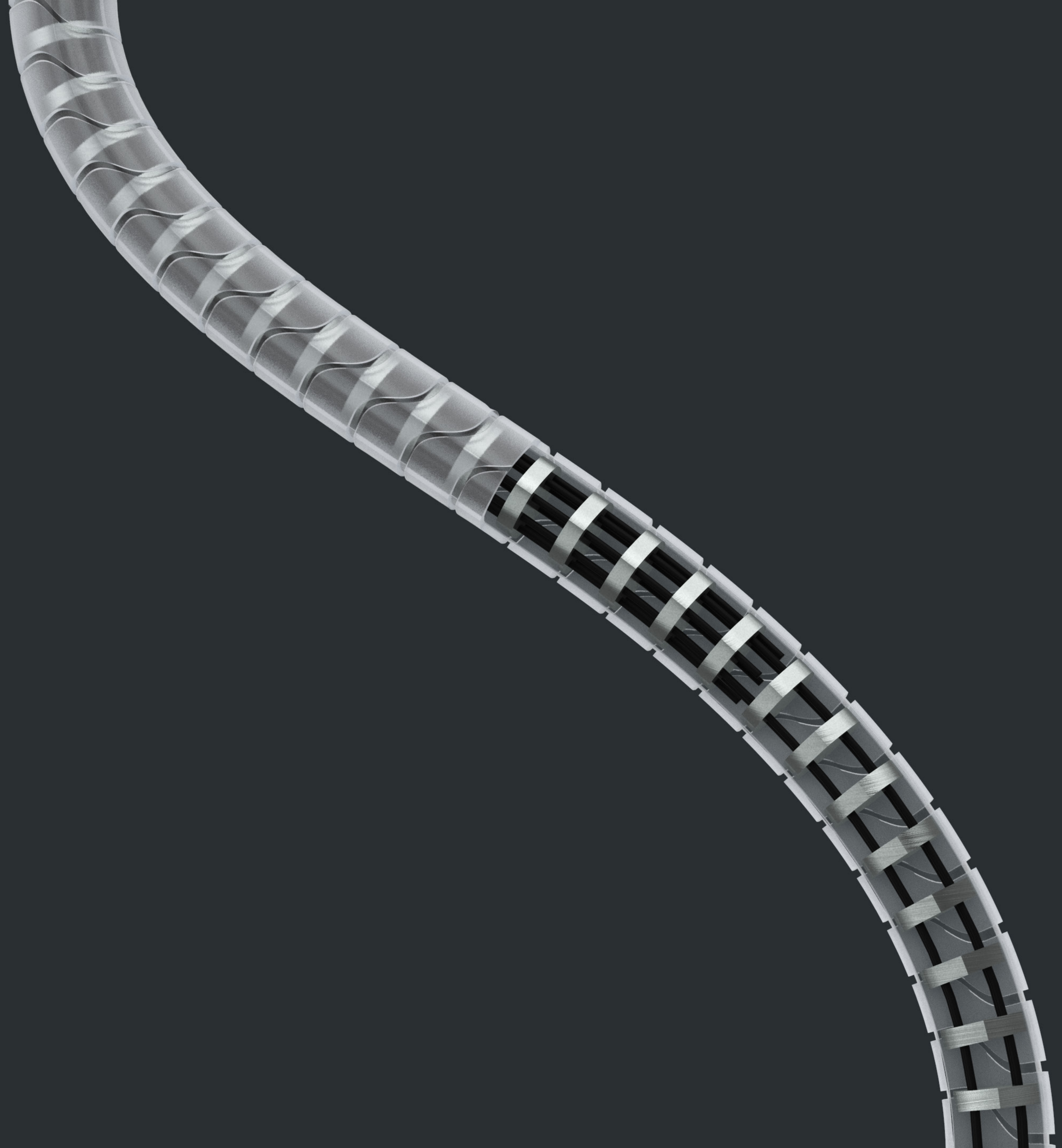
A mechanical altered body made by Thomas Thwaites that forces his body to emulate the physiology and behavior of a goat, from his 2016 book: Goat Man.



The landscape of the near future will be uneven, random, and oftentimes hazardous. The onset of changes that will be brought about by climate change as well as the implementation of increasingly invasive and interconnected technologies into the development and management of urban infrastructure are many. While my design does not seek to be a solution to any of these problems, it does seek to expand human capability by giving them access to new modes of interaction, behavior, and locomotion; all things that would make navigating an uneven landscape less tenuous and more bearable. It is also a counter to the solutionism and narrow mindedness found in previous generations of body augmenting technologies, mistakes that next generation of neural prosthetics (those controlled via the use of BCI's) seems set to repeat. More than anything this design is about wonder and inspiring the future designers and developers of this technology to expand the possibilities of what they can do with this emerging technology and to not limit its use to mere human replication or facsimile. In this way, zoomorphic extended body is an umbrella term that can encompass a variety of designs and forms that adapt different animal traits, behaviors, and forms into designs that build on the body to offer their users a variety of new abilities and modes of interaction. This one in particular is based on the physiological adaptations of the giant pacific octopus. In a design that works around the body, it extends out from the user's hips. These appendages, just like the tentacles of the giant pacific octopus, offer the user a means of locomotion through any environment as well as the ability to interact with, grab, and manipulate objects in their environment. They are also semi autonomous. One of the many unique features of the octopus tentacle is the ability to act independently from the octopus in order to perform simple tasks and movements but still be available when more directed interactions are necessary. I have adapted this feature for locomotion within my design allowing the user to more easily control and direct the design via their thoughts. In this way, the octopus extended body will act as a more natural extension of the user's body rather than as a separate entity to be controlled.

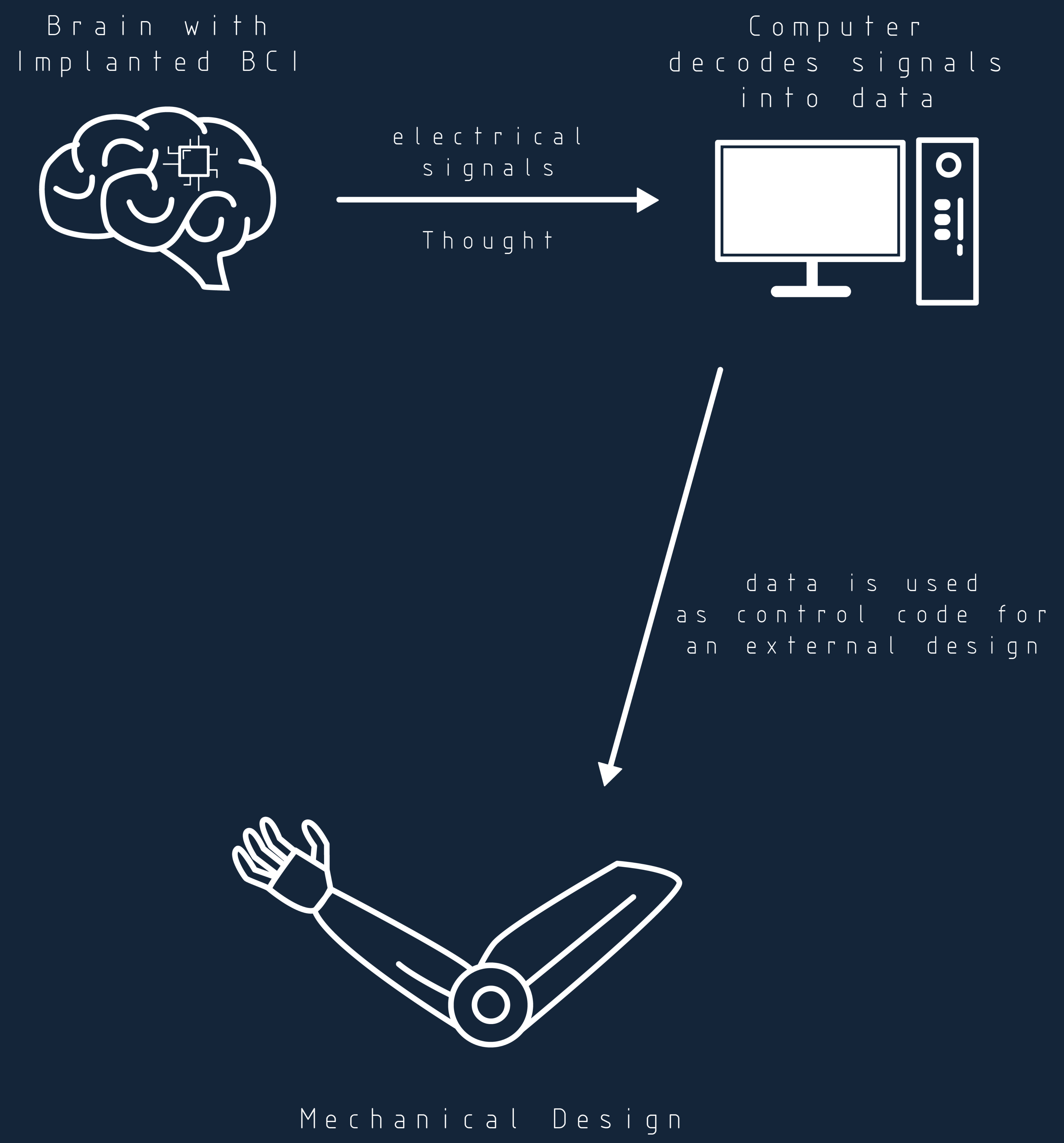


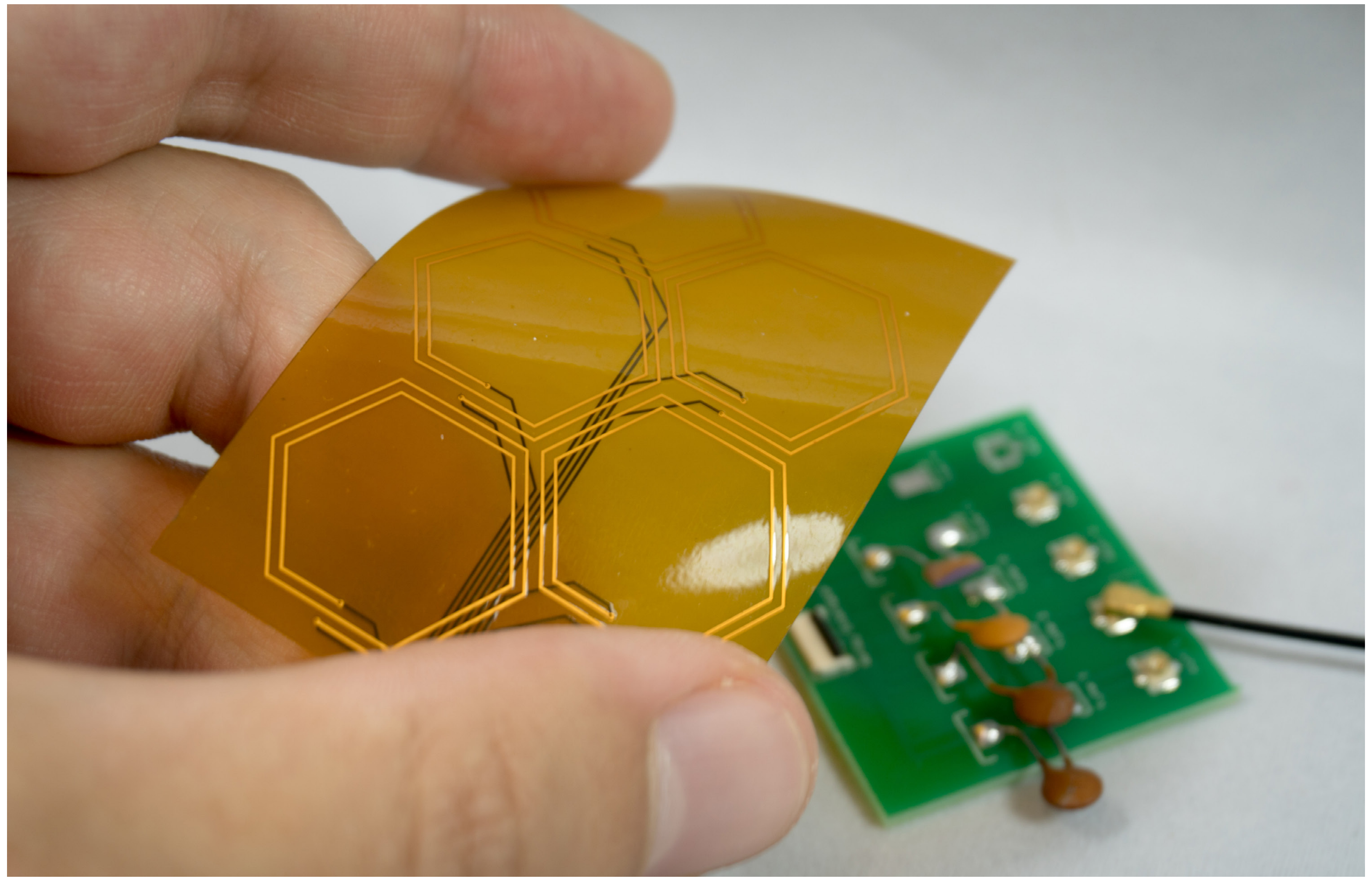
The octopus extended body has a variety of potential uses and modes of interaction. Its design is not only inspired by, but mechanically replicates the physiology of the octopus tentacle, an appendage with potentially more uses than our own arm and hands. Just as my design is a proposal to not limit the potential of the emerging technology behind neural prosthetics and BCI's, I also do not want to limit the design itself by suggesting a particular mode of use or ground it within a specific professional context. I will expand on this reasoning later, but having a specific use, mode of use, or users for this design would have drastically altered my approach to creating and prototyping it. Due to the limitations placed on the development of this design due to it being developed during a global pandemic, I was not able to effectively test many modes of use and interaction. However, his limitation has actually worked to the design's advantage, as it has resulted in a design whose form and function are limitless rather than limited. In the following sections I will expand on some of the concepts I already briefly discussed, as well as the development of the design itself, and give some explanation on the underlying technology that supports my octopus extended body.

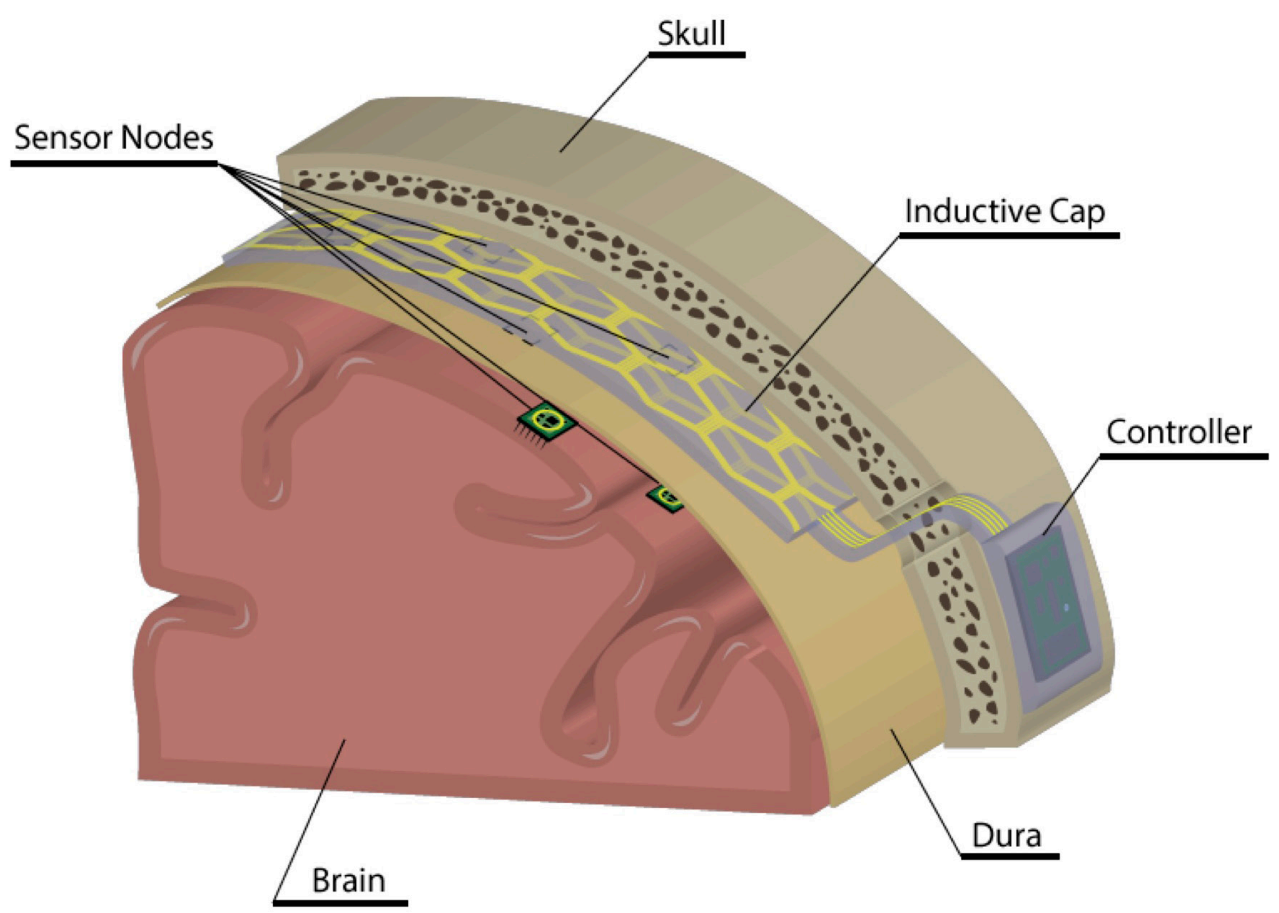


WHAT ARE BCI'S?

To have an understanding of my design, one also needs to understand the underlying technology supporting it and why I chose to structure my design around that technology. BCI's or Brain Computer Interfaces is an umbrella term for a variety of technologies that allow a user's brain to interact, communicate, or control an external computerized device using the electrical signals in their brain. These include neural control interfaces (NRI's), mind machine interfaces (MMI's), direct neural interfaces (DNI's), and brain machine interfaces (BMI's); the last of which, my design will rely upon. The way this is accomplished is via a device that can read the electrical signals within your brain and translate that information into data that can then be used to control a computerized device. These interfaces can be as simple and innocuous as a skull cap lined with sensors or as complex as a surgical implant within a person's skull. While there are a variety of applications currently being researched and explored with BCI's, I'm going to focus on a particular case where BMI's are being researched and produced in order to allow users to control robotic mechanisms. The research in question is taking place at the Neuroengineering and Neuromotion Laboratory also known as the Borton Lab at Brown University. The labs' key discovery that they are building all of their research around is the fact that regardless of the state of the individual's body, the signals that are sent out of the brain to direct and control different parts of the body are always present. What this means is that even in cases where individuals are missing limbs or suffering from some form of paralysis, the signals to control those limbs and other body parts are still being sent out but are "interrupted" by the individual's disability. This is true regardless of what is blocking those signals, whether that be loss of limb, spinal cord damage, or any other form of nerve damage. The lab's stated goal is to "design, develop, and deploy neurotechnology to better understand the nervous system and improve human lives."







Two photos provided by the Borton Lab. One, a technical diagram of how Braincell is implanted into a person. The other, a sample of the implantable material; Neurofilm.

The way the Borton lab is doing this is by mapping and tracking the different electrical pathways in the brain and testing to determine what motor functions they correspond to. This is being done through a variety of projects most notably Braincell and Neurofilm which consist of small flexible electronic implants within the brain which read, record, and transmit the electrical signals they read to a computer. They are also researching how artificially stimulating those pathways can give users feedback from external robotics and prosthetic devices that are not part of their own bodies. This is being done to support the development of proprio prosthetics which are prosthetics which allow their users to experience tactile feedback like touch and temperature through the prosthetic devices themselves. Lastly, they are also conducting research into how they can translate those mapped pathways into digital data that can then be used to control robotic and prosthetic devices. This can be seen as the meta goal for the lab as a whole, as it is developing technology that can then be used within commercial prosthetic devices to allow their users to either regain control of their bodies or to operate robotic replacements for parts of their bodies which may be missing.

The applied research of all of these projects is to enable disabled people, particularly those with quadriplegia (paralysis from the neck down), to use implanted BCI's like Neurofilm and Braincell to control robotic apparatuses that take the place of their physical bodies. In testing these have been externally operated robotic arms; but in production, it's theorized that this technology could be used to operate more mechanically complex prosthetics and orthotics. This would replace the less complex myoelectric powered prosthetics which rely upon electrodes attached to residual muscles in a users limb in order to "activate" or control a prosthetic limb or the even more primitive body activated prosthetic designs which are only capable of rudimentary motions and actions. These new prosthetics dubbed "Neural Prosthetics" would rely upon the human brain to determine their actions and behaviors. The main question I asked myself when looking through all this research was, **"if this technology allows users to control robotic mechanisms using only their thoughts, why is it only being used to facilitate designs that focus on only replicating human forms and human functions?"**

"the boundary between physical and non-physical is very imprecise for us"

- Donna Haraway, Cyborg Manifesto

WHAT IS A MECHANICAL EXTENDED BODY?

A term that may have been confusing up until this point is the term "extended body." What is it? What does it mean? And why am I choosing to use it to describe my project? Much of my research for my thesis was focused around prosthetic limbs. How they are designed, how they function, what underlying technology do they make use of, ect. But for all of their unique and variable designs, they all rely upon a fairly heavy accommodation; the loss of one's body. Prosthetic arms and legs are made as facsimiles of the limbs they are meant to replace. This intended goal seems obvious, after all, most of our constructed environments and technology are made with the assumption that those using it are fully able bodied. What this results in is a group of designs that focus on two things. One, the replication of a form that resembles a human limb. Two, the replication of a form that imitates the behaviors and functions of a human limb. While these two factors do not seem like great limitations in and of themselves, they are limitations that often work at odds with each other and the materials used to construct their designs. What results are a series of designs with extreme tradeoffs. Designs like the OpenBionics Hero Arm are made large and cumbersome even with the use of lightweight materials in order to accommodate dense battery packs and complex circuitry and servos is an example of one extreme. On the other hand, there are numerous designs that only provide the wearer with something that approximates the look and feel of a human limb with almost none of its functionality. These designs are often composed of soft materials like silicon and other elastomers to more accurately replicate a human limb and are mostly static or only capable of very basic functions. Through my research I found that designs that do not focus heavily on these two factors and instead focus on adapting nonhuman forms and functions show much more potential functionality and work more harmoniously with the technology and materials they are constructed with than the examples i just mentioned; but that is something that I will be discussing in a later section.

This is a photo of Open Bionics most advanced prosthetic, the Hero Arm, which relies upon myoelectric sensors to perform simple gripping functions. Despite its relative simplicity, it retains a similar size and shape regardless of the user's age or body type.

One of the co-discoverers of CRISPR, Jennifer Doudna, giving a speech on gene editing at the National Human Genome Research Institute (NHGRI)

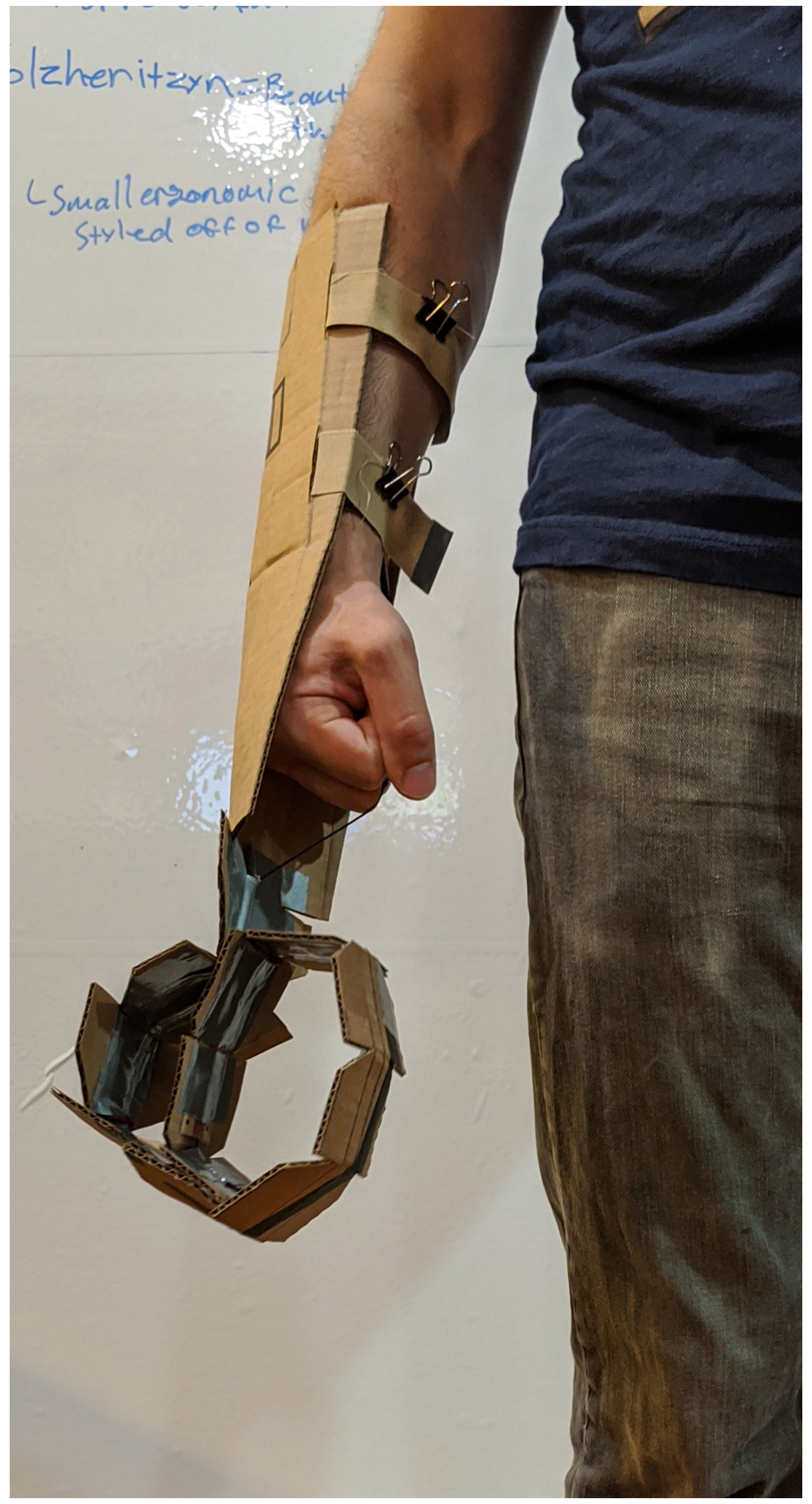
A reasonable question someone might ask when faced with these questions is; if all of these problems arise from trying to replicate an organic form like the human body with materials that are artificial and inorganic, why not seek to replicate those forms with something organic in nature? While practices like regrowing limbs or cloning limbs from tissue may be a possibility sometime in the future, what this question actually speaks to is the larger practice of gene editing within the human body. More specifically, it speaks to the use of one particular scientific breakthrough in the field of gene editing through the use of CRISPR/ CAS-9. CRISPR, short for clustered regularly interspaced short palindromic repeats, is a practice of selectively editing parts of a dna sequence in order to cause specific mutations. What is revolutionary about CRISPR compared to earlier forms of gene editing is that it is programmable and can be populated with any genetic code researchers desire. This is done by giving it a copy of DNA that you would want to be modified and then putting that system into a living cell. CRISPR/ CAS-9 then works by cutting apart the DNA sequence within that cell and inserting its new genetic code causing a mutation. While more controlled than earlier methods of gene editing, CRISPR is still not a 100 percent precise or accurate tool. Some genes cannot be combined and sometimes mutations are not consistent across multiple hosts, still it shows a lot of potential in creating controlled programmable mutations to an individual's genetic code. The future potential of this technology includes things like removing retroviruses such as herpes and other viruses which are incurable but live within cells as hosts as well as the creation of cancer fighting cells that have been improved with CRISPR. For this reason, CRISPR based therapies have already been approved as early as 2015 in China in order to fight lung cancer.

According to one of the discoverers of CRISPR, Jennifer Doudna, this technology also presents a lot of dangers. While genetic engineering is going to change many industries such as healthcare from changing its approach from treatment to a larger focus on preventative care via gene therapy, it presents significant dangers in that it's a tool that is easy to use, but hard to predict the long term consequences of. Since genes and the codes that compose them are interlinked in mostly unknown ways; and gene expression (the physical result from changing a gene) can be linked to and changed by a myriad of factors, it is unethical to make changes to an individual's genetic code while not knowing all of the consequences of those changes as it violates their consent by subjecting them to unknown consequences. To quote William Hurlbut a biological research ethicist:

"genetics is a very fragile balance...theres lots of reasons to be cautious here, its not genes are like Legos or Mr Potato head where you just change a trait by changing a couple genes, genes interact with one another so we need to have a very realistic scientific appraisal of what we're doing...theres plenty of work to do for the next half a century or century before we even ponder anything with regard to genetic enhancements"

So it is not feasible to even be making adaptive changes to the human body in the near future, let alone incorporate non-human physiologies like that of an octopus or other organism into that of a living person. The near future of this technology according to its discoverer, Doudna, is in monogene (single gene) therapy and the treatment of genetic diseases, not the manipulation of advantageous traits in the body. Mechanical Design technologies such as those of BCI's and neural prosthetics, however, are currently being researched and actively applied to the human body and do not possess the adverse ethical concerns of genetic engineering as they are much less invasive in terms of the alterations to the body that they require.

So how does all of this relate to the term extended body? Extended body is a term that I have constructed that works at odds with another term: altered body. Thus far, I have only discussed designs that focus on bodily replacement. These are designs that quite literally take the place of limbs and other parts of the body. My previously mentioned examples seek to replicate some of the forms and functions of the limbs they replace. Some of the examples that I will show later take this one step further, and seek to improve upon the abilities of the wearer by enhancing or augmenting their abilities based on specific use cases. All of these designs are what I am calling Altered Body Designs, they are designs that seek to replace parts of the body with mechanical duplicates. But all altered body designs rely upon that core accommodation that was previously mentioned: the loss or replacement of one's body. For congenital and acquired amputees, this accommodation is already met, which is why they are the sole users of altered body designs. But how can we apply these designs to not only disabled individuals but able-bodied individuals as well? **Any design that requires the user to remove a fully functioning part of their body in order to accommodate is unethical in nature, so too is any design that proposes permanently altering one's genetic code.** This is where the concept of extended body comes in. Unlike altered body designs that seek to replace the body in order to enhance it, extended body designs work around the body to extend it. Extended body designs are more than just orthotics, however. Orthotics also work around the body, but they often do so in order to support it or to augment the functions of existing parts of the body. Such is the case from simple designs like leg braces to more complex designs like exoskeletons. Where Extended body designs differ is that they seek to add functionality to the human body not merely augment it. These designs can take many forms: an extra limb, a mechanical tail, or even a bodily conforming suit that gives you some of the abilities of an octopus.



An early altered body prototype inspired by the physiology of the octopus. This would replace the user's arm with a tentacle, changing how they interact with others and their environment.

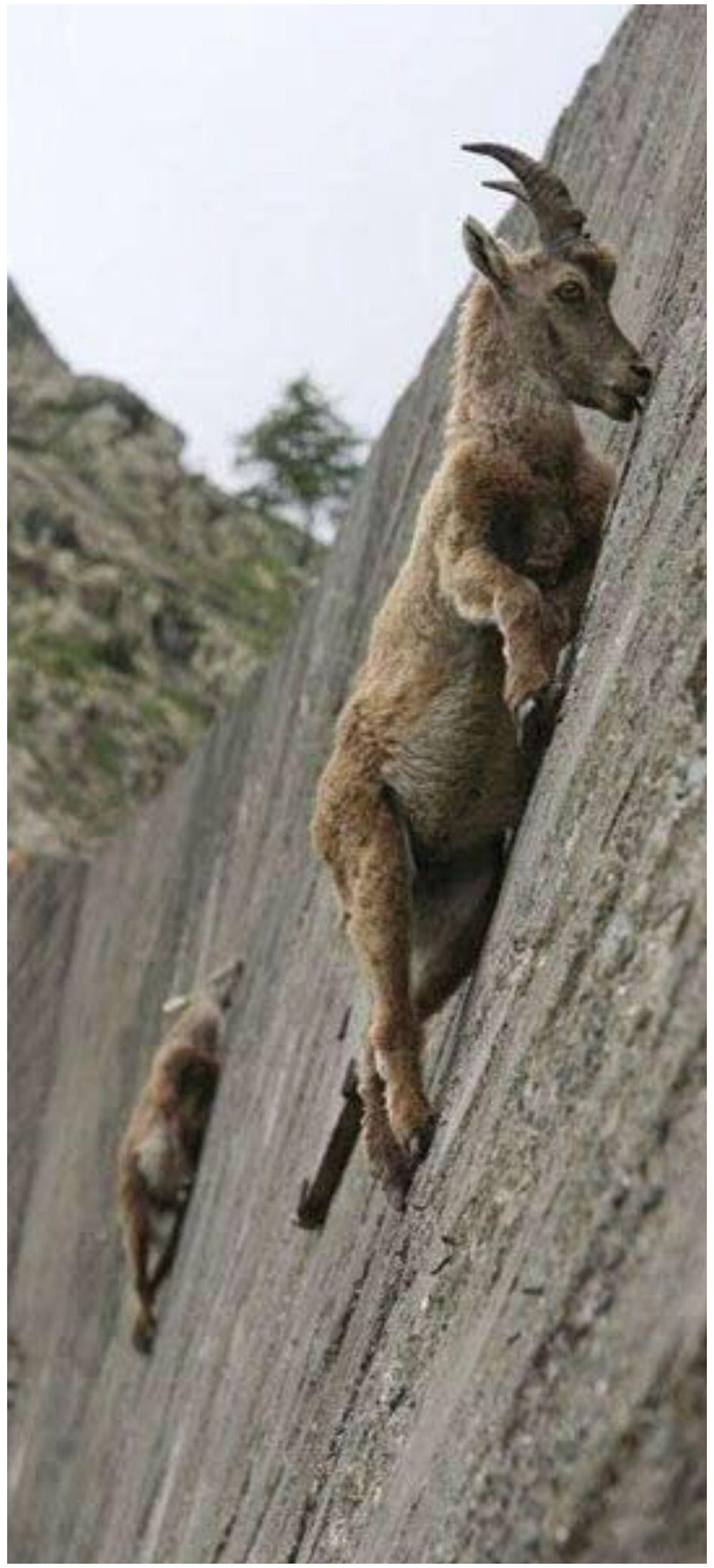
"Our environment is becoming alive, or at least quasi-alive, and in ways specifically and fundamentally analogous to ourselves..."

- Phillip K. Dick, The Android and the Human

THE PHILOSOPHY OF ZOOMORPHIC DESIGN

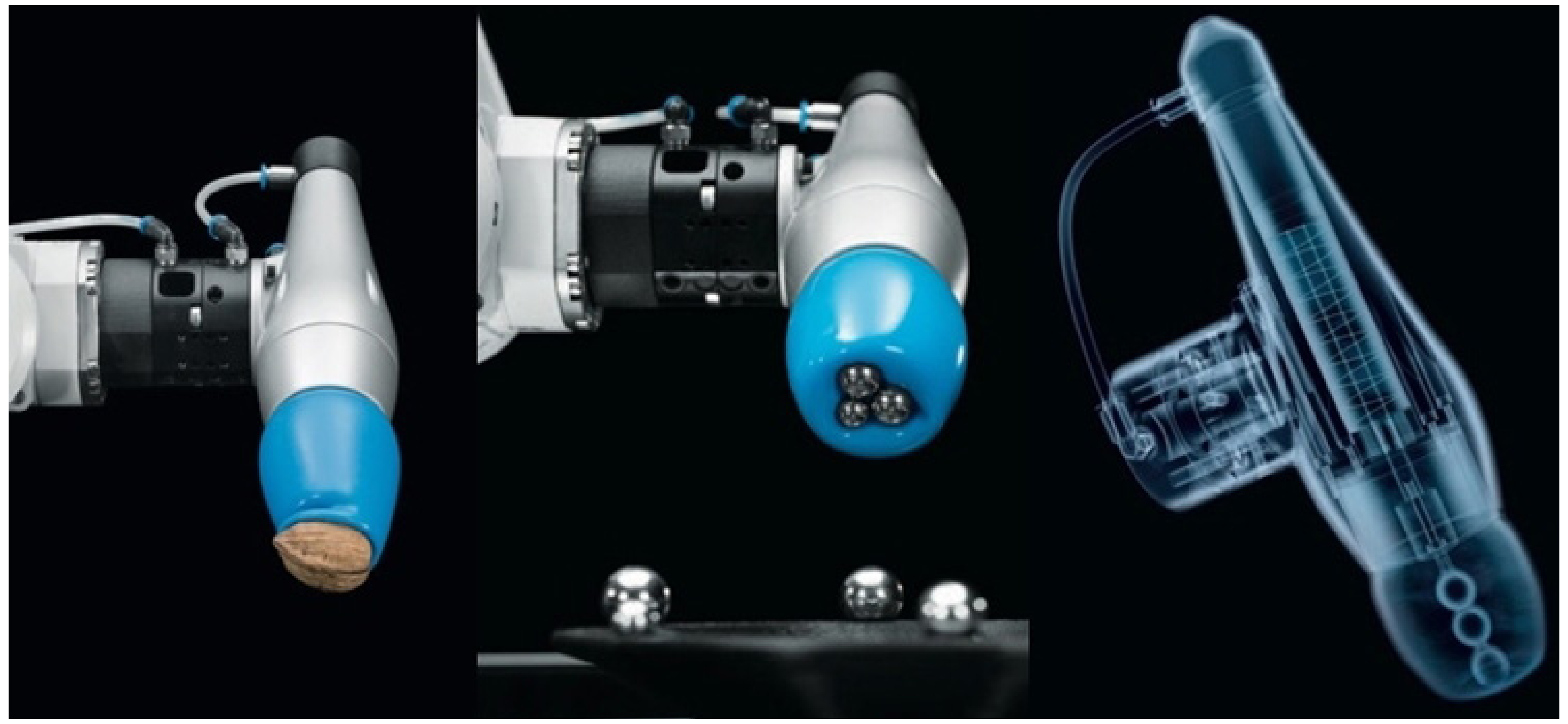
If the value of mechanical extended body designs is that they are not constrained by the narrow focus of human biological replication, why did I choose instead to replicate another biological form in that of the octopus? To answer that, I need to first explain the value and ethos behind zoomorphism and biomimicry in general. I mentioned earlier that altered body designs that instead rely upon adapting nonhuman forms and functions show much more potential than those that focused solely on human facsimile. Instead these designs focus on creating specialized prosthetics for extreme use cases. Though many of these prosthetics don't work well as a general replacement for the parts of the body they replace, they do represent an improvement in terms of the performance and capability they possess within their specific uses. Perhaps the best example of the advantages of this type of design comes from their use by athlete, model, and actress; Aimee Mullins. A double transtibial amputee (below the knee), Mullins relies upon mechanical altered bodies (prosthetics) in order to walk, run, and perform any functions required of a human leg. Despite her disability, in the 1996 Paralympic Games she set 3 world records via the use of a nonhuman based prosthetic and also became the first female amputee in history to compete in the NCAA Division 1 for track and field. She did this not only through her extreme skill as an athlete, but through the use of a new type of prosthetic leg called a Flex-Foot Cheetah, which as its name implies is heavily inspired by biology of a cheetah. Where this particular altered body excels is in the act of running, however, it behaves poorly when trying to replicate any other form or motion of the human leg. Unlike the human leg, the Flex Foot is not a permanent fixture on the human body and can be easily interchanged with a number of other forms. Aimee Mullins herself has 12 different pairs of legs that she alternates between depending on the situation, most of which feature an inhuman like quality such as longer and skinnier than natural legs for modeling purposes or legs with carved designs and murals made from wood for the run-

A photo of Hugh Herr utilizing his customized climbing prosthetic juxtaposed with a photo of an ibex. Both make use of specialized physical attributes in their legs to more easily perform a specific task, climbing a rock face.



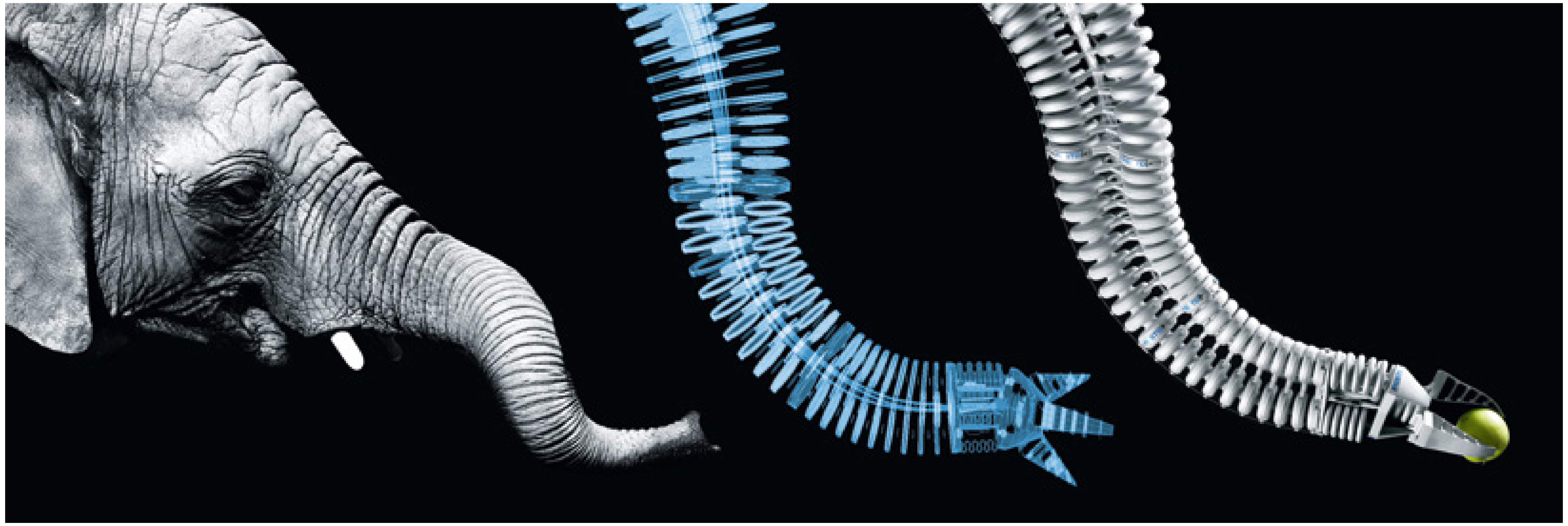
way. The same can be said for another athlete who made use of animal biomimicry in the design of their lower limb prosthetic, american engineer, biophysicist, and climber Hugh Herr. A recreational rock climber who is also a transtibial amputee, Herr created an unique pair of prosthetic legs built specifically to aid in rock climbing. These legs have a small foot allowing for easier fittings within narrow or hard to grip rock outcropping and crevices as well as telescoping legs that allow for traversal across wider outcroppings than is normally humanly possible. Much of the design of these prosthetics borrow heavily from the physiology of creatures like the ibex or mountain goats who have evolved similar physiological adaptations to traverse in similar environments. Similar to the Flex Foot prosthetic, however, these designs are not well suited to other activities outside of rock climbing like walking or even running comfortably.

Olympian, actress, and model Aimee Mullins is seen here making use of her specialized prosthetic, the flex-foot cheetah, to improve on her ability to run. It does this by borrowing physiological adaptations better suited for fast lightweight running from the cheetah, pictured above.



What both of these altered body designs show along with other commercial and non-commercial designs is the value of biomimicry and non-human traits when it comes to designing altered bodies. More specifically, it shows that traits and behaviors that rely upon the physical form of animals show the most potential when adapted to an altered body design. This is also true for the field of robotics. Companies like Festo have had great success at adapting the physiologies of chameleons, elephants, and cephalopods into a variety of soft and rigid mechanical forms like grippers and arms. But just because there are designs for robotics and extended bodies being produced does not mean that those designs are all necessarily desired. Specifically when it comes to replacing part of the body with something that can't perform all or some of the functions of a fully functioning limb is a difficult accommodation to ask of any individual. It is for that reason that the most prolific of nonhuman designs, at least in the field of altered bodies, are those made for extreme use cases as previously mentioned. This is also why I am making mechanical extended bodies rather than altered bodies, as the wearer of these altered bodies would not have to give up human functionality in order to accomodate the design but can still benefit from the additional functionality that the nonhuman design brings.

A variety of robotics that borrow from animal physiology to improve upon their functionality. These robotics from the company, Festo, excel at deconstructing an animal's traits that are based on their physical abilities and applying them to a mechanical form.



"Having a scuba tank in a thick kelp forest is not optimal for me, I want to more like an amphibious animal"

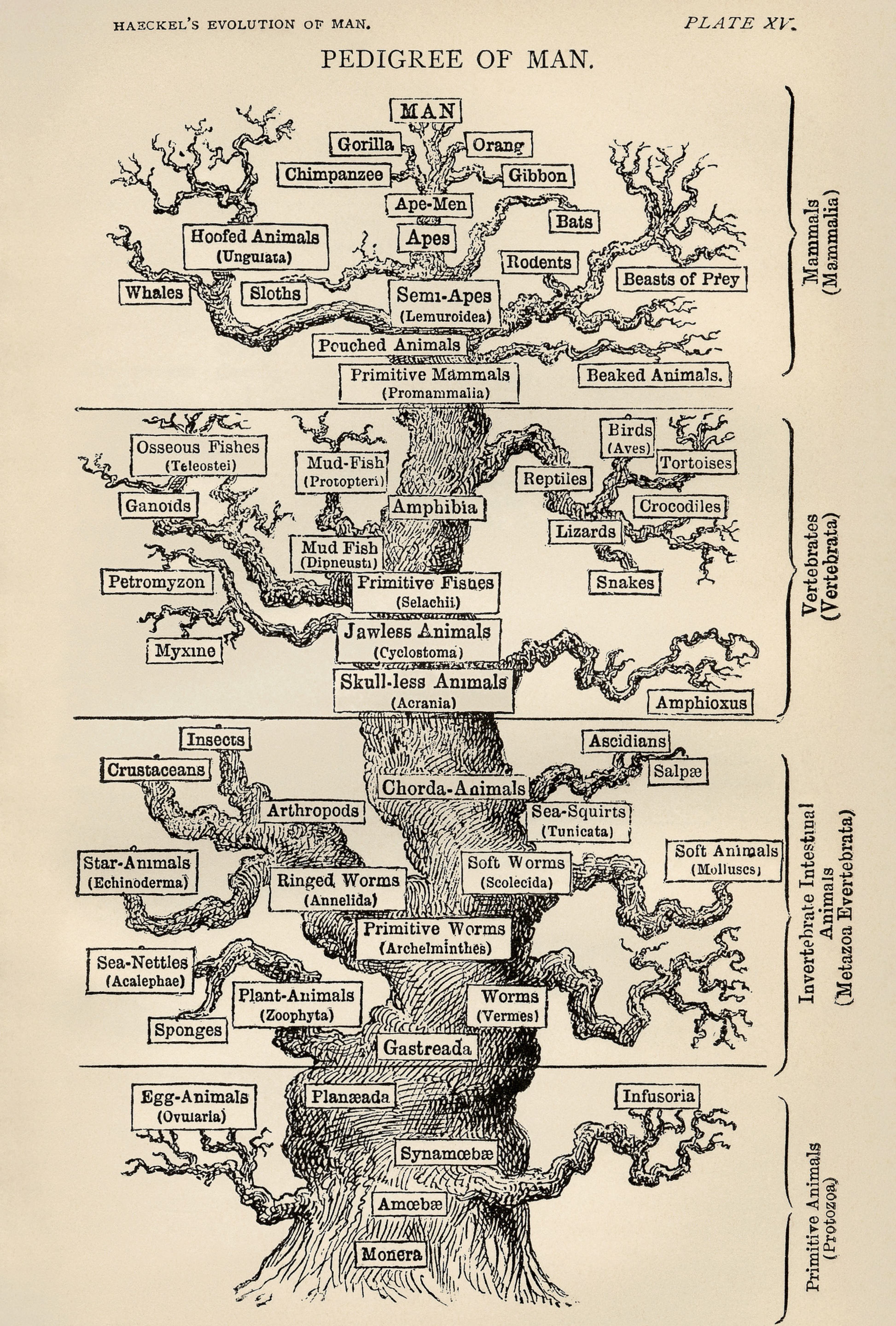
-Craig Foster, My Octopus Teacher

WHY OCTOPUS?

Of all of the animals I could have used to inform my design, why did I go with an octopus? One of the overarching goals for my thesis is to show the value and potential of incorporating non-human forms into and around the human body. I have also shown that animal physiologies in particular display many advantageous traits when performing specific activities that we simply are not capable of via our own static physiologies. I have also shown that though non-human animals possess a number of traits and behaviors that we ourselves do not, the traits and behaviors that are made possible by an animals physiological adaptations (the physical form of their bodies) have the most potential to be mechanically replicated in other forms like those of prosthetics. So the next question that would need to be answered is; what animal physiologies should I adapt into my extended body design and why?

The previous examples of mechanical altered bodies (prosthetics) that I have shown have almost universally been informed by mammalian physiology. The reason for this is obvious, as we ourselves are mammals and there are many parallels between our physiology and that of other mammals. A human leg can be interchanged with a cheetah leg or an ibex leg for example as they are both legs and serve similar functions even if each is better suited for different activities like running or rock climbing. But if I am to show that nonhuman physiologies have value, I need to show the most extreme inhuman example that I can. To the side you can see an illustrated copy of one of the earliest taxonomy of animals from Ernst Haeckel's 1879 book Evolution of Man. If you take note of the locations of homo sapiens (us) and octopi, you will notice that they are on nearly opposite sides of the illustration. That is because humans and octopi are so far removed from one another that they only share the highest taxonomy category, that

This is a photo of one of the earliest known taxonomic trees ever made. It is taken from Ernst Haeckel's 1879 book, Evolution of Man. You can see that man and octopus (molluscs / soft animals) are on opposite sides of the tree highlighting their extreme genealogical differences.



This is a photo of an octopus moving about in its natural habitat. Does any part of its anatomy seem similar or analogous to a human's in any way? Are any of its movements, interactions, or behaviors human-like in any way?

of both being in the same kingdom, Animalia. It is for this reason that **I chose to base my design on the physiology of the octopus as they are so distant from us biologically that they exhibit many unique traits and behaviors that are fundamentally different from our own.** After all, if something so far removed from us biologically could be incorporated into our own body, then the physiology of any creature could as well. And what creature is more inhuman in its appearance, behavior, and biology than an octopus?

The fact that the form and behavior of octopus are so dissimilar from our own did present some interesting problems in and of themselves. Throughout this design process, Ive been using narrative filmmaking as an important reference to inform how I prototype, construct, and conceptualize my design. The designers and artists who fabricate designs for monsters, aliens, and creatures in cinema have crafted a number of techniques over the years to create designs that are intentionally more or less compelling based solely on their appearance and behaviors. It's an oversimplification of this process, but as a shorthand the inclusion of more or less human traits and behaviors is a common metric used for making a design more or less sympathetic to an audience. As previously stated, an octopus exhibits virtually no human-like behaviors or features apart from having stereoscopic vision. Choosing the octopus as the template for my design presents not only an opportunity to co-opt its many and unique traits and behaviors, but also to deviate from the conventional wisdom set by film makers and designers alike, remember: almost all of those previously shown animal prosthetic designs were informed by mammalian specimens. For my design to be successful it has to overcome an innate stigma to non-human forms that has been ingrained in our psyche through generational wariness towards the unknown and reinforcement through our media.

As I have repeatedly stated, the octopus presents many variable traits and behaviors due to how biologically distant they are from us. But That also means there are more traits and behaviors than can be consolidated into one unitary design. From my collected research I made a short list of some of the unique traits and behaviors that I was able to identify that were uniquely "non-human." These included things such as limb regrowth, internal jet propulsion, multiple hearts, a decentralized nervous system, ink dispersal,

Sympathetic Creature Design
in Narrative Fiction

color and texture change through chromatophores, and much more. From that running list I narrowed it down to traits that could be mechanically or materially replicated as well as traits that would enable new modes of mobility and interaction within the constantly shifting landscape of near future environments. My design does not specifically address some of the concerns of the near future such as how climate change and the increasing prevalence of smart city infrastructure will drastically change our living and work environments. Despite this, I believe that the constantly shifting landscape caused by issues such as these will require us to be adaptable and experimental in our approach to previously mundane activities. Even simple activities such as walking can become difficult when increased sea level rise leads to an increased frequency in flooding. My octopus extended body is not a solution to some or all of these problems, but it is a provocation. A provocation to not only challenge the conventional wisdom present with the design of mechanical altered bodies to be more creative with their application of materials and technology, but to also challenge how we may further evolve and develop our technology alongside ourselves.

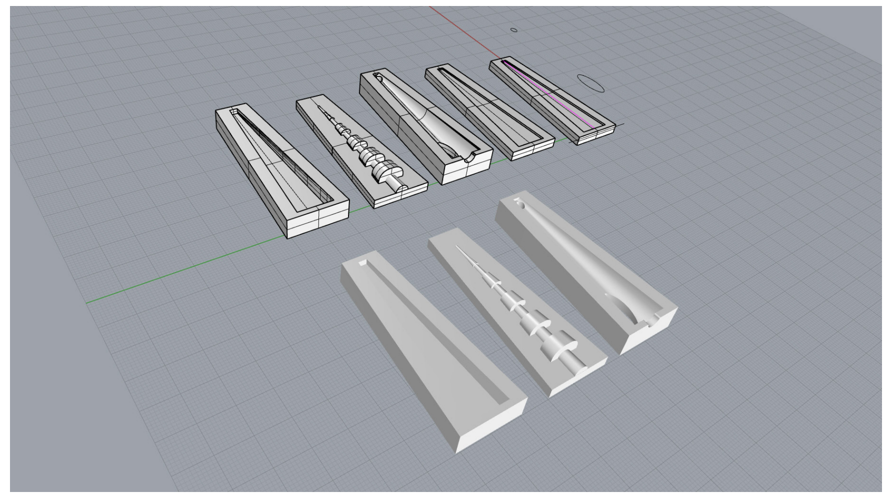
A simple diagram that sorts a variety of fictional creatures and aliens from more sympathetic to less sympathetic based on the quantity of human features they have. Note that there are duplicates of some creature designs that are sorted onto different points on the diagram when more human features are added or taken away.

design developing process

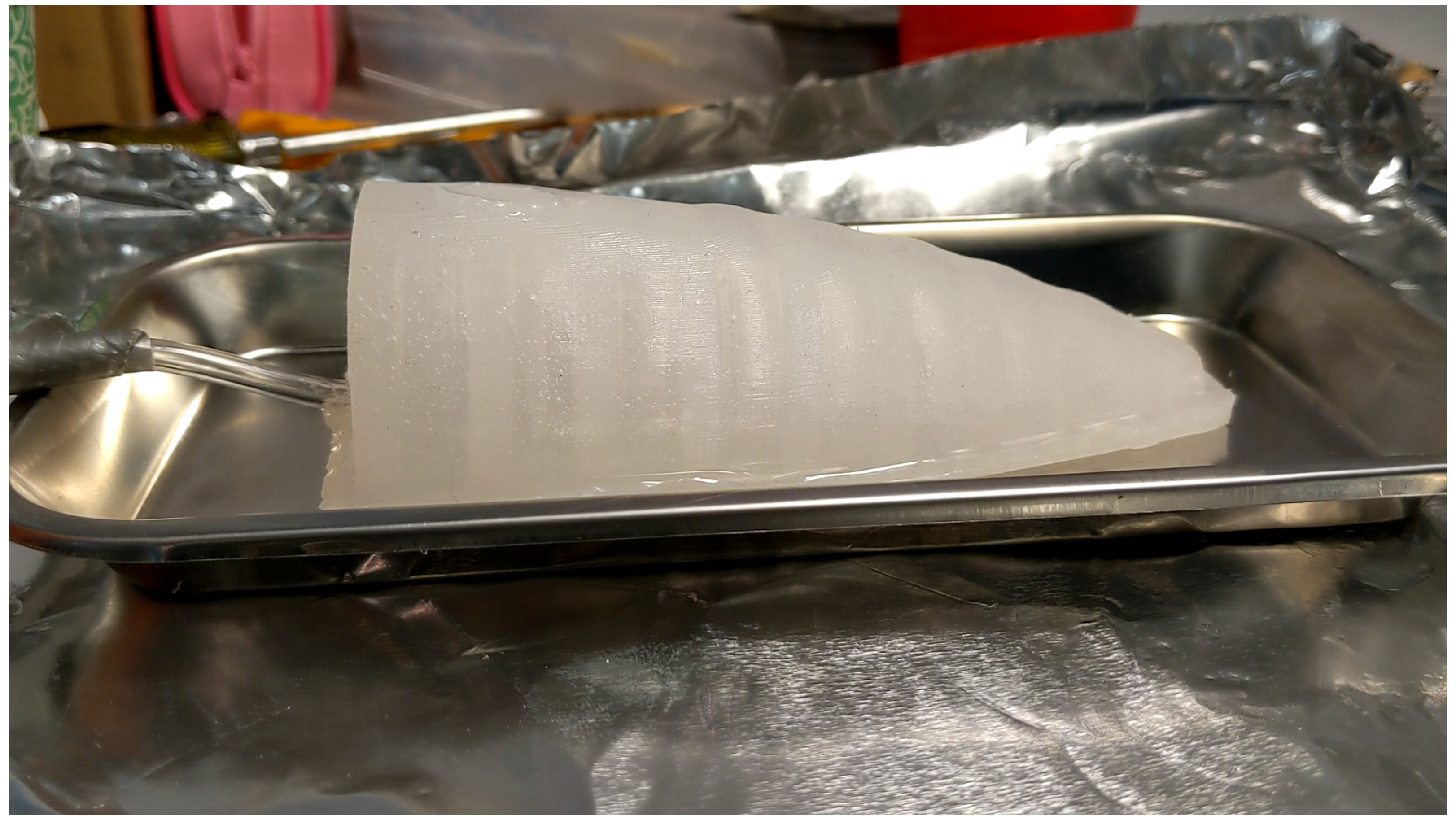
Prototyping Mechanical Functions

One of if not the most important aspect of my design was the adaptation of the octopus' physiology into a mechanical design. I knew that traditional mechanical designs that rely upon rigid structures and strong joints to create a strong articulated form would not work. This is because these methodologies are built on our own physiological structures of having a rigid skeleton that is then being actuated by the surrounding tissues, an octopus on the other hand is an invertebrate and does not possess any of these same structures. It is this distinct lack of structure that allows for many of its variable movements and interactions. So I began by analyzing and deconstructing soft robotic structures and even experimenting with creating a few designs of my own. These designs were composed of silicon or soft plastic and were actuated by air pressure changing their volume in order to create articulation and changes in form. The goal was to identify a structure that could be actuated with air, was composed of soft materials, and accurately replicated the behavior of an octopus' tentacle. Through this experimentation I discovered that soft robotics designs had two major flaws. The first, is that they are not particularly strong, which would become a problem for supporting the human body or manipulating objects. The second, is that they would require an air supply equal to their volume as well as a compressor and motor to actuate the design; two things that would not only require a larger amount of power, but would also make the design larger and more cumbersome.

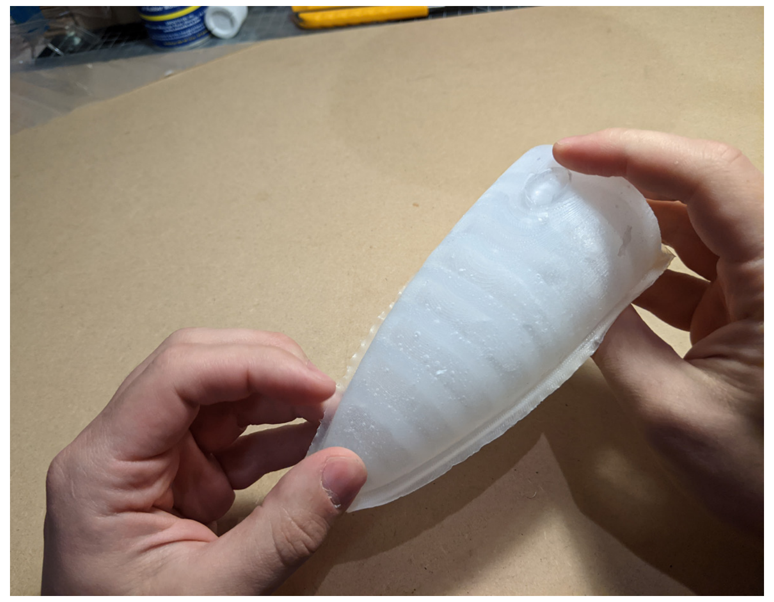
A flash prototype soft gripper made from plastic sheeting, cups, and water. It utilizes the change in volume of the water around an object in order to grip it while only applying a minimal amount of pressure to the object.

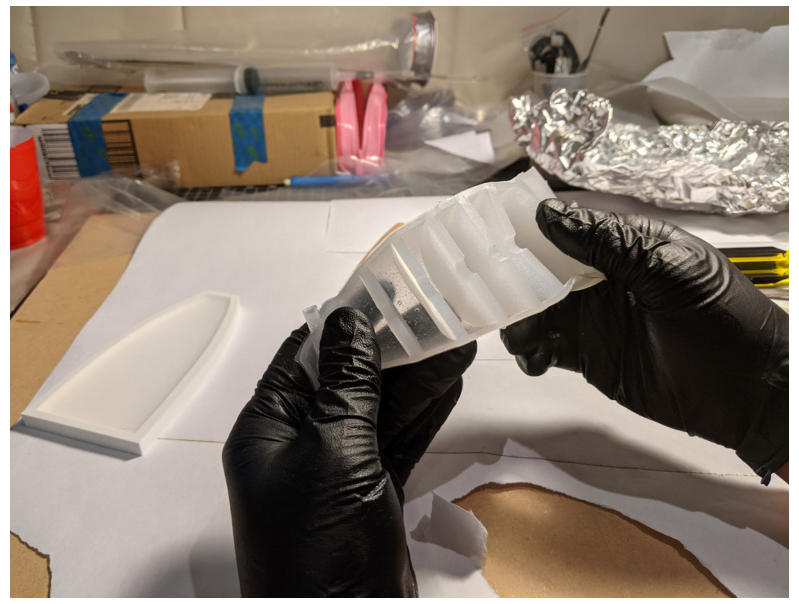
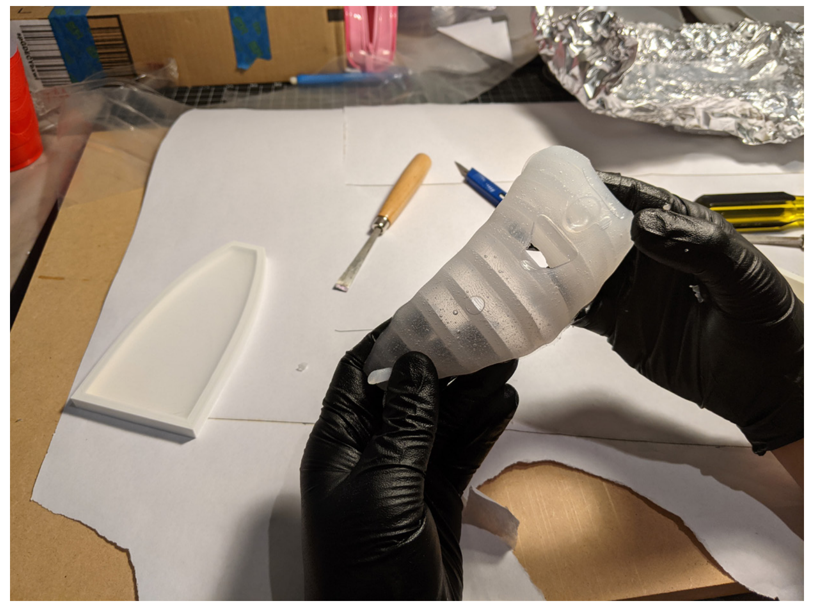
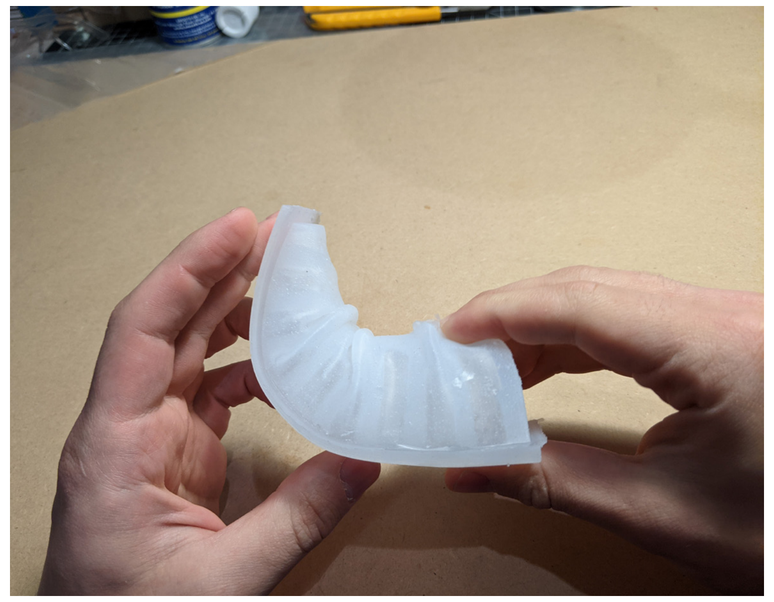
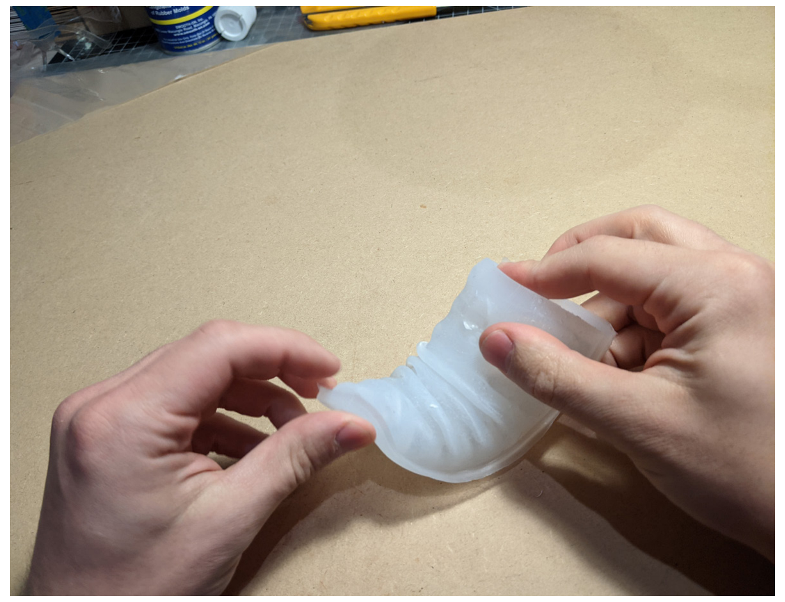


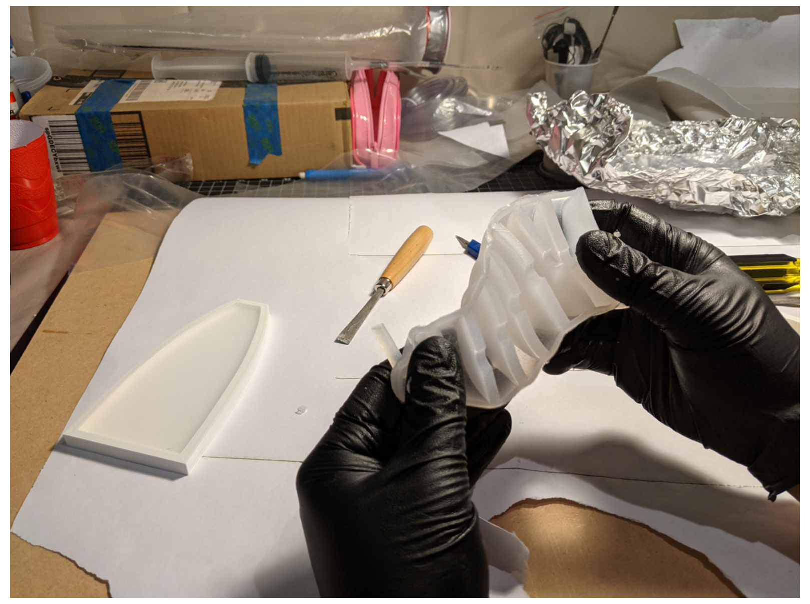
One of the earliest silicon tentacles I made utilizing a two part molding system that required the two halves to be bonded together after molding.



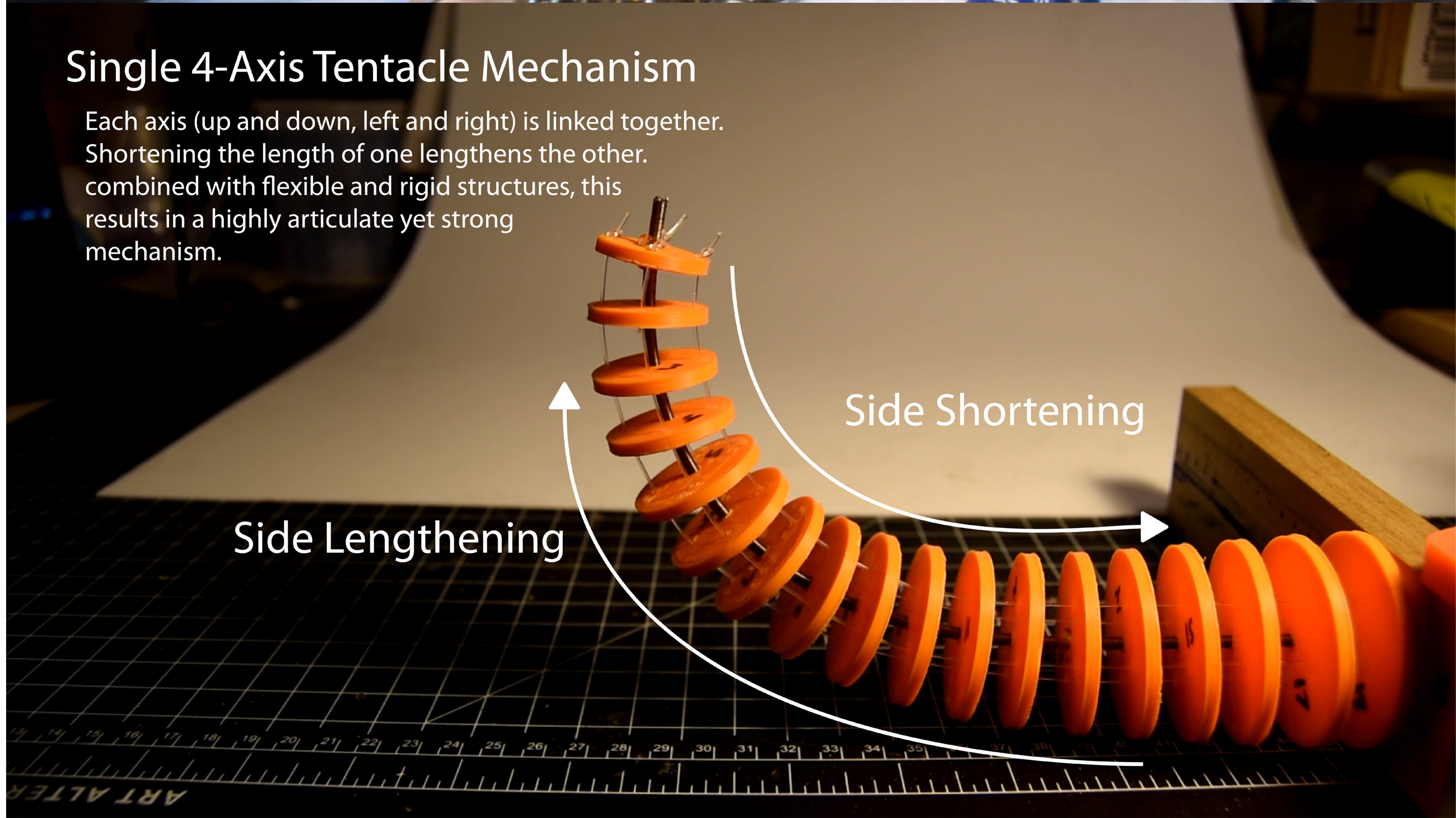
A variety of soft robotic tentacle prototypes. These prototypes are composed of a soft and flexible silicon that are cast with deliberately shaped air cavities on the inside that connect to an external tube. The prototypes are activated by evacuating or adding air to the prototypes via an external device. This action either inflates or deflates the air cavities inside the prototypes resulting in a single axis of motion in each of the tentacles.



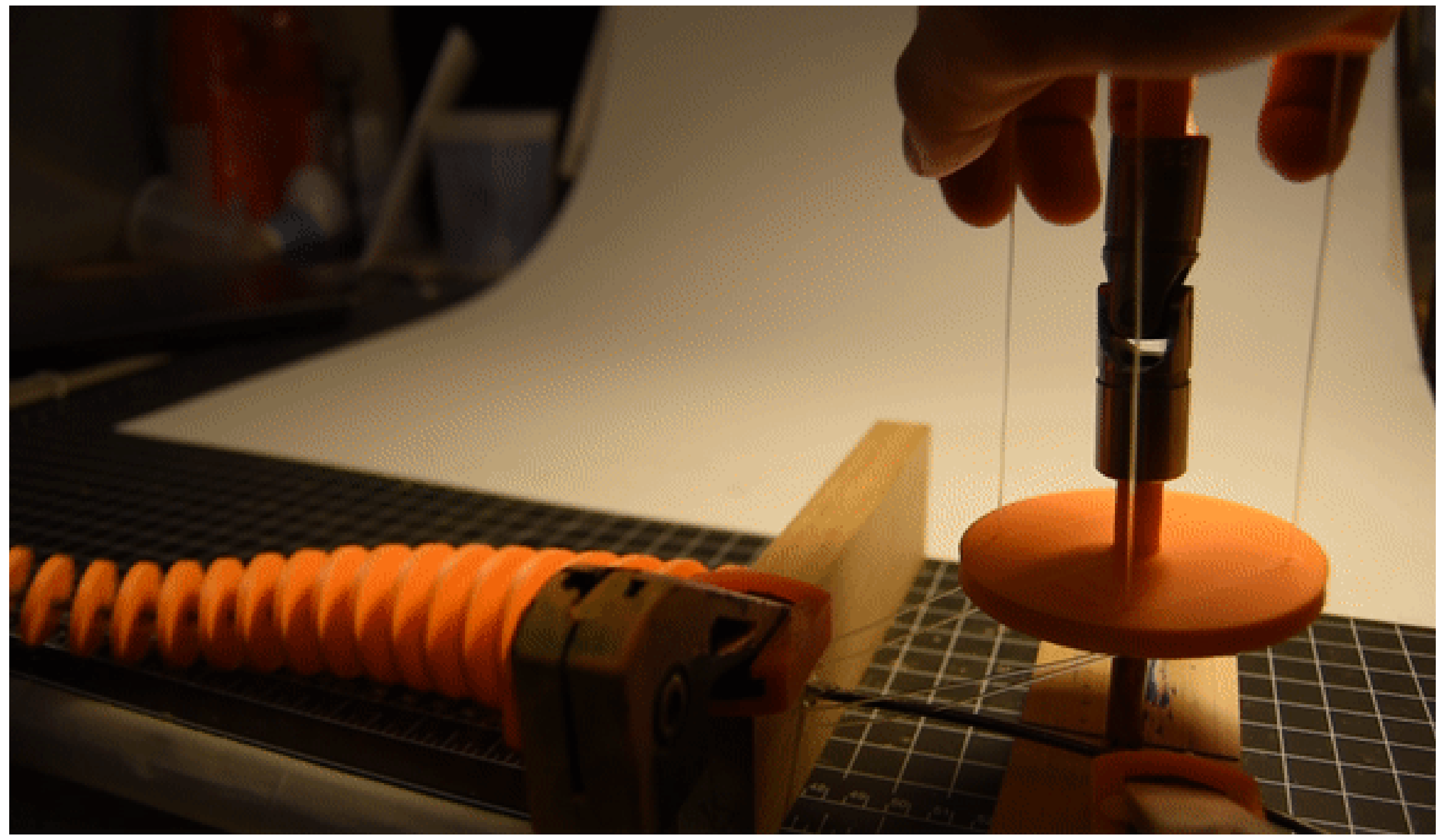
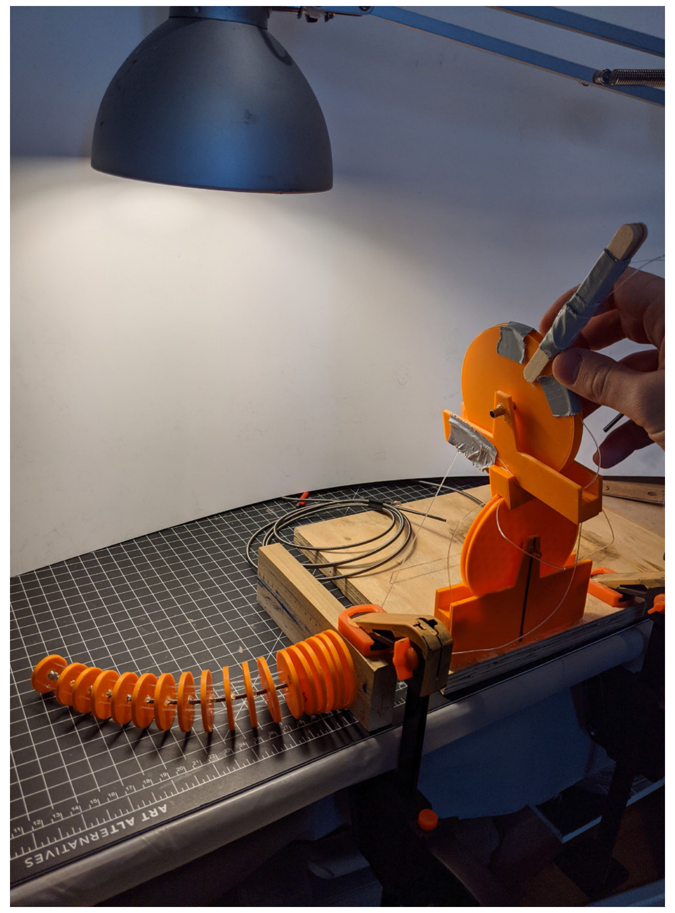


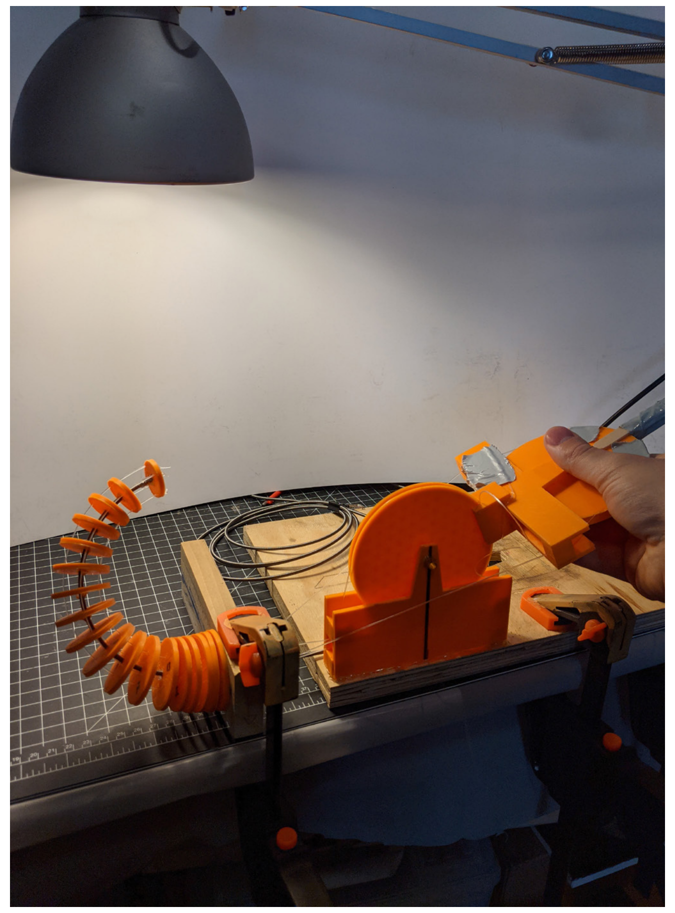
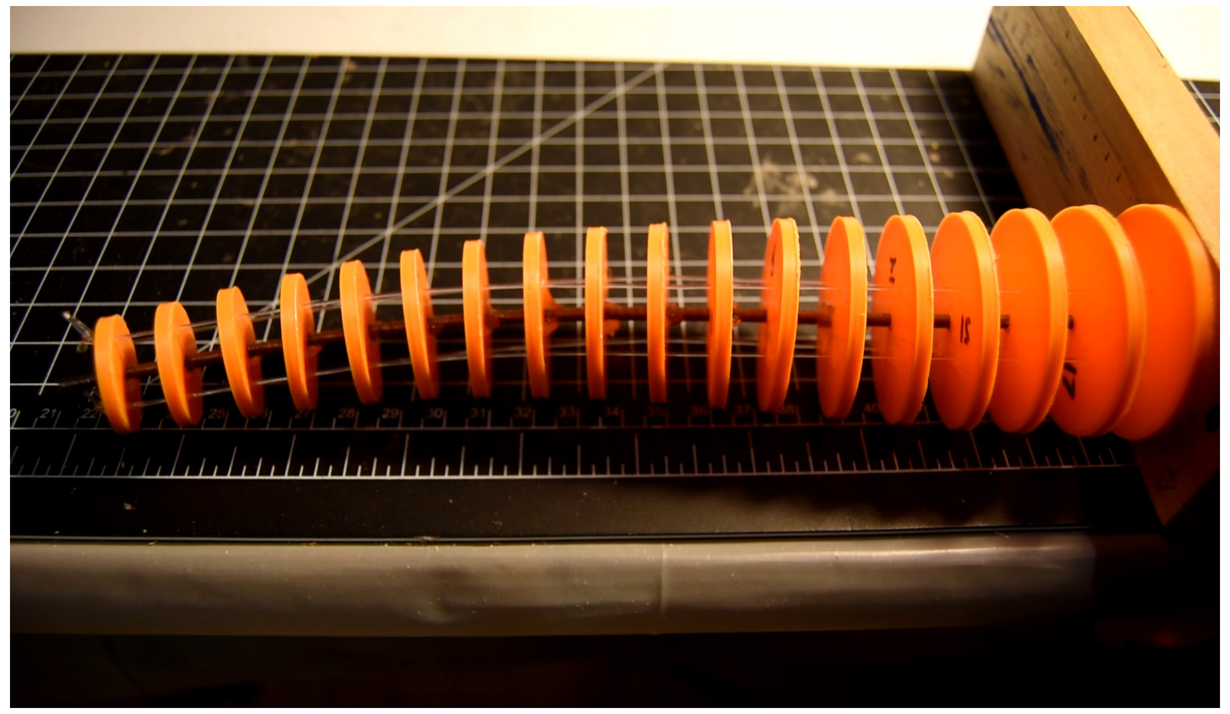
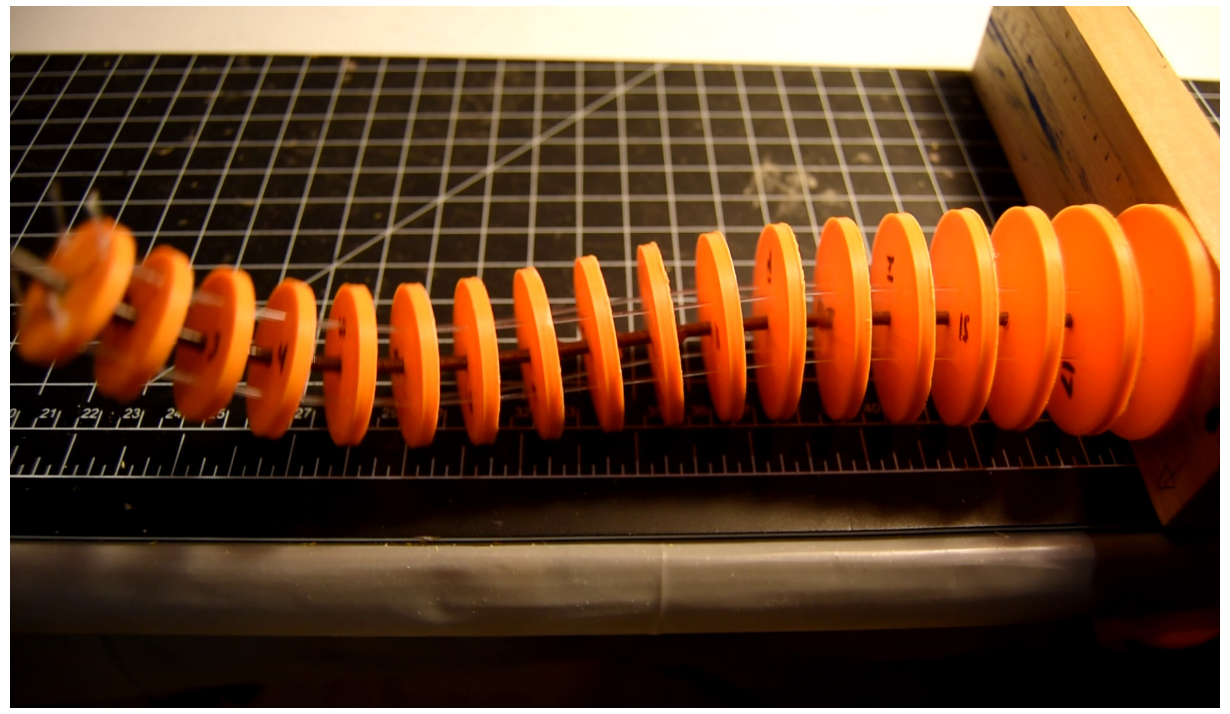
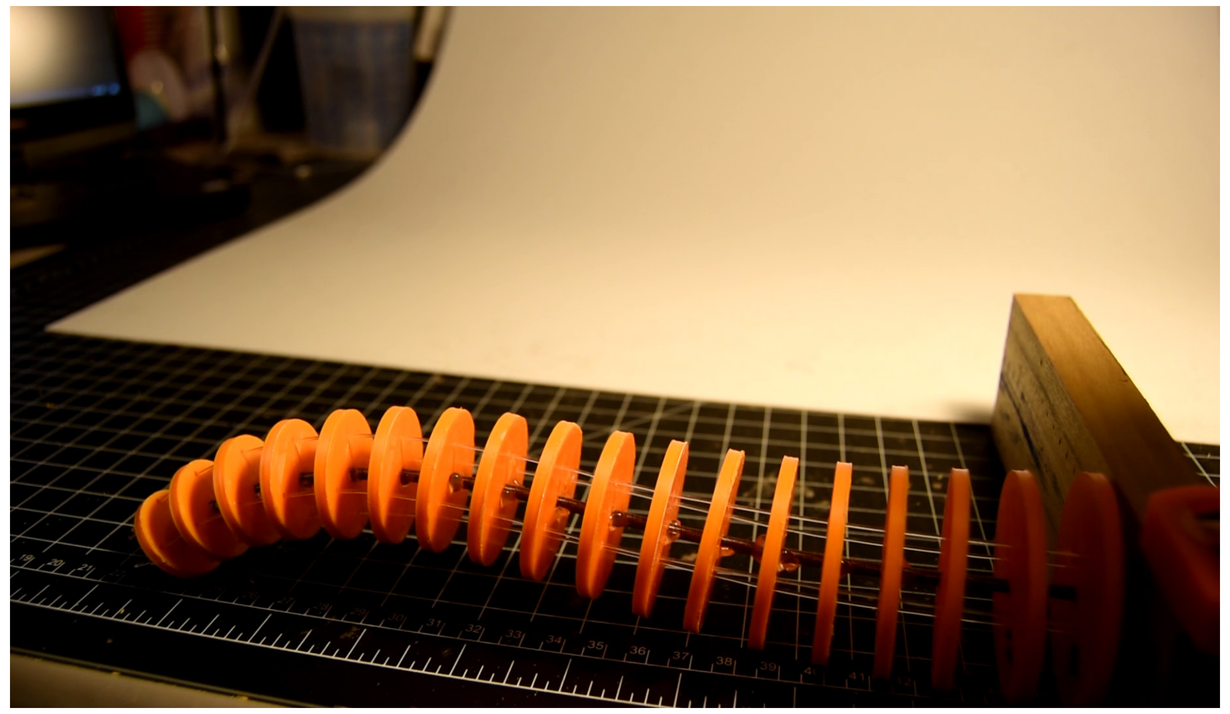
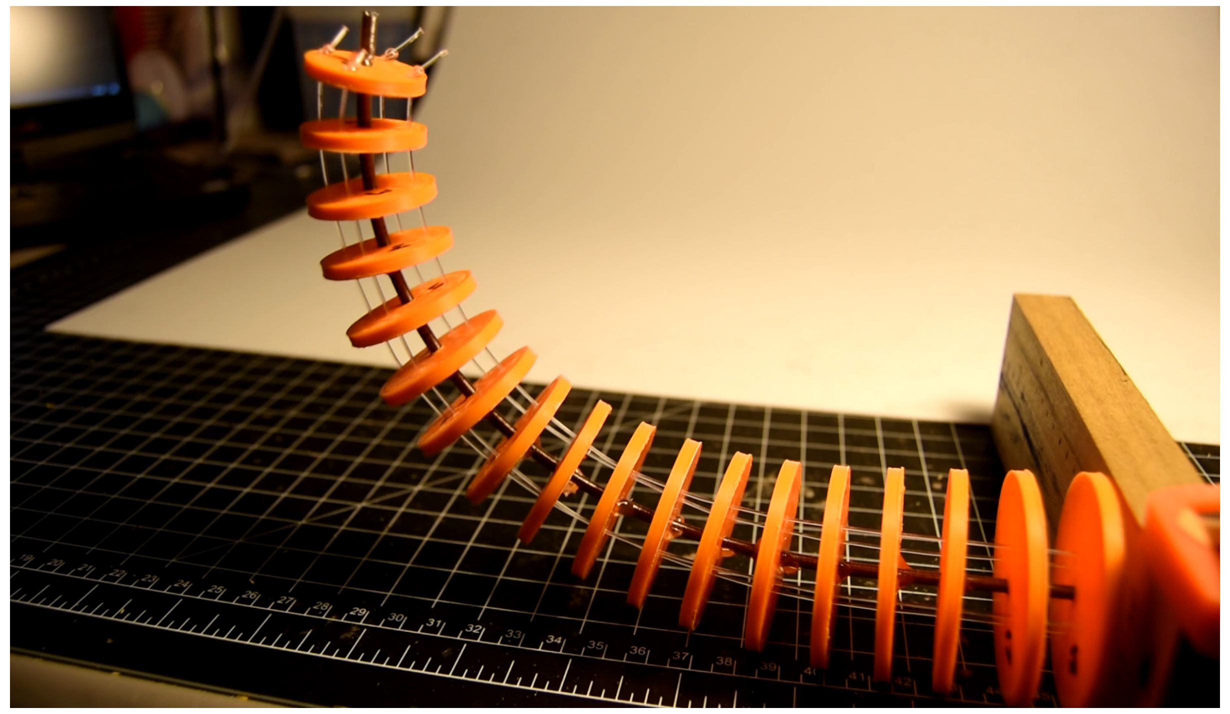
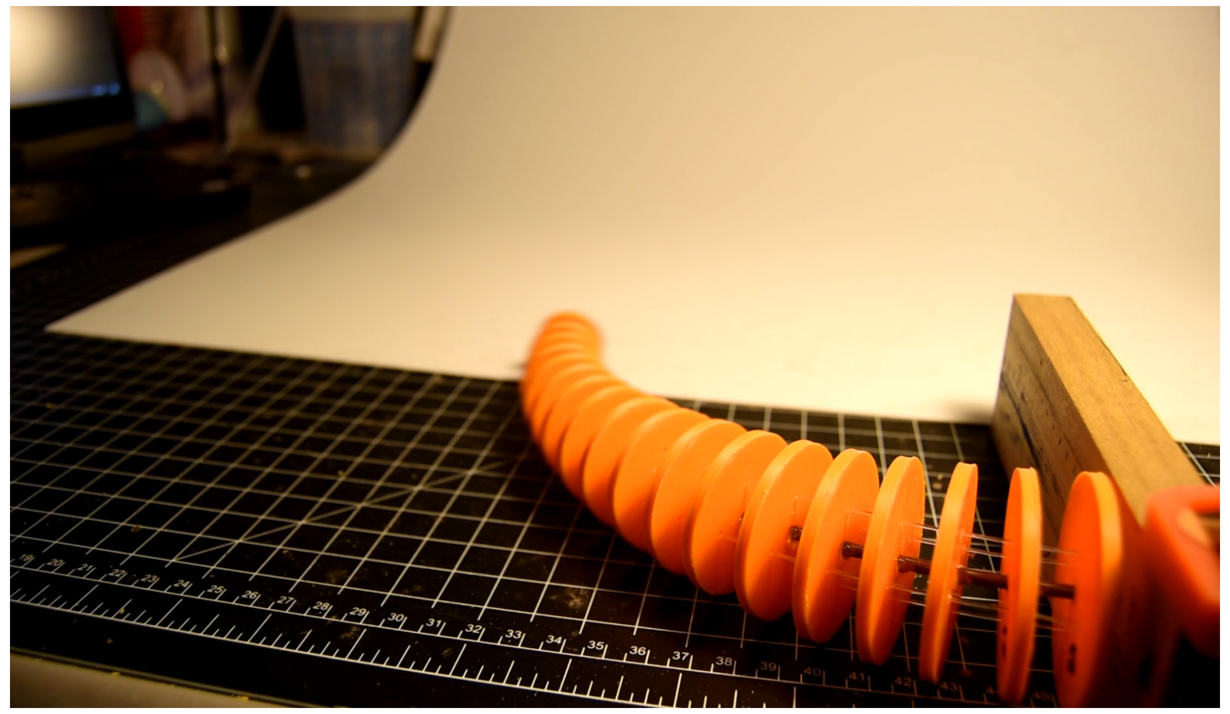
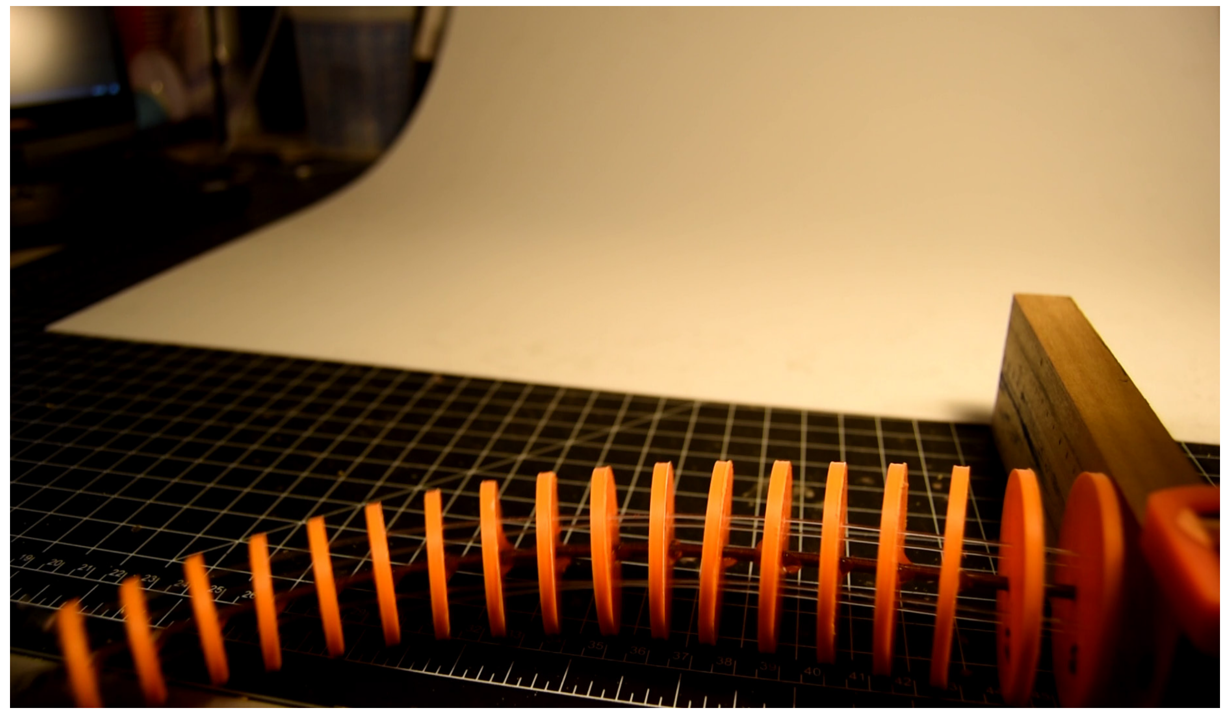
An alternative to the soft robotic design would be a more rigid robotic system composed of stronger materials that are not reliant upon a large air supply and compressor system in order to be activated. One important problem in regards to rigid robotic systems, however, is that they can be hazardous and potentially harmful. This is due to the rigid materials that compose their designs as well as the high amounts of power needed for activating those designs. The solution is a hybrid system of soft and rigid robotics. Looking towards the special FX industry, I identified a number of designs and mechanisms that have been developed for the creation of animatronic and special FX puppets. These designs are composed of a number of interconnected discs or flexible materials that are then actuated by different types of cable mechanisms. Despite their simplicity, these mechanisms are great at replicating numerous organic behaviors like those of tails, vertebrae, necks, and even tentacles. They are also strong enough to support being coated and covered and other materials and manipulate objects as well as light enough to be controlled and operated by a puppeteer using a simple controller. My extended body would make use of a similar mechanical methodology, but also be coated in a soft rubberized material in order to avoid any of the potential hazards associated with a rigid robotic design.



Top:
Special FX mechanic, Stephen Norrington, working on a cable activated puppet of a "face hugger" on the set of the 1979 film, Alien.

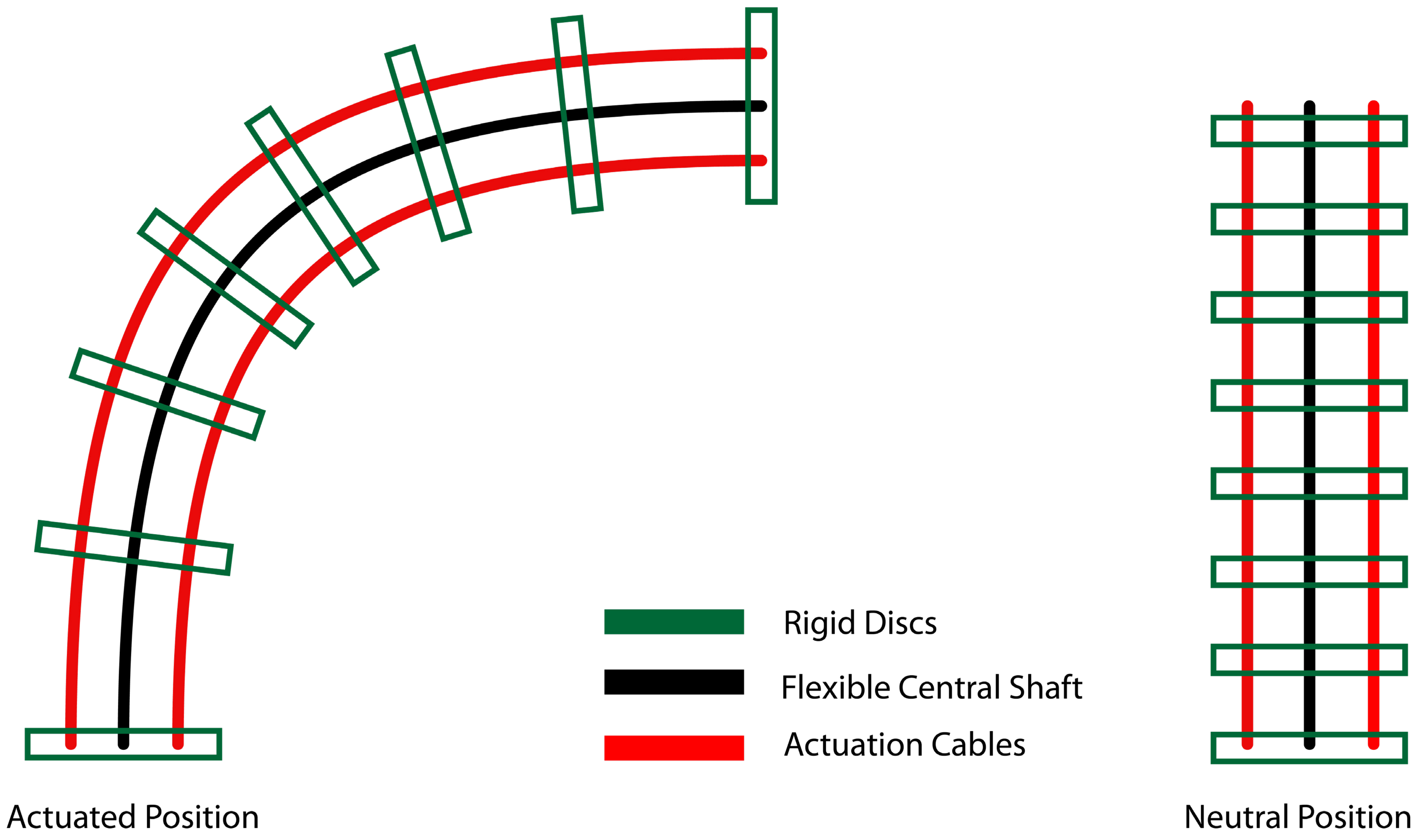
Bottom:
A short explanation of how my 4 axis cable mechanism functions.

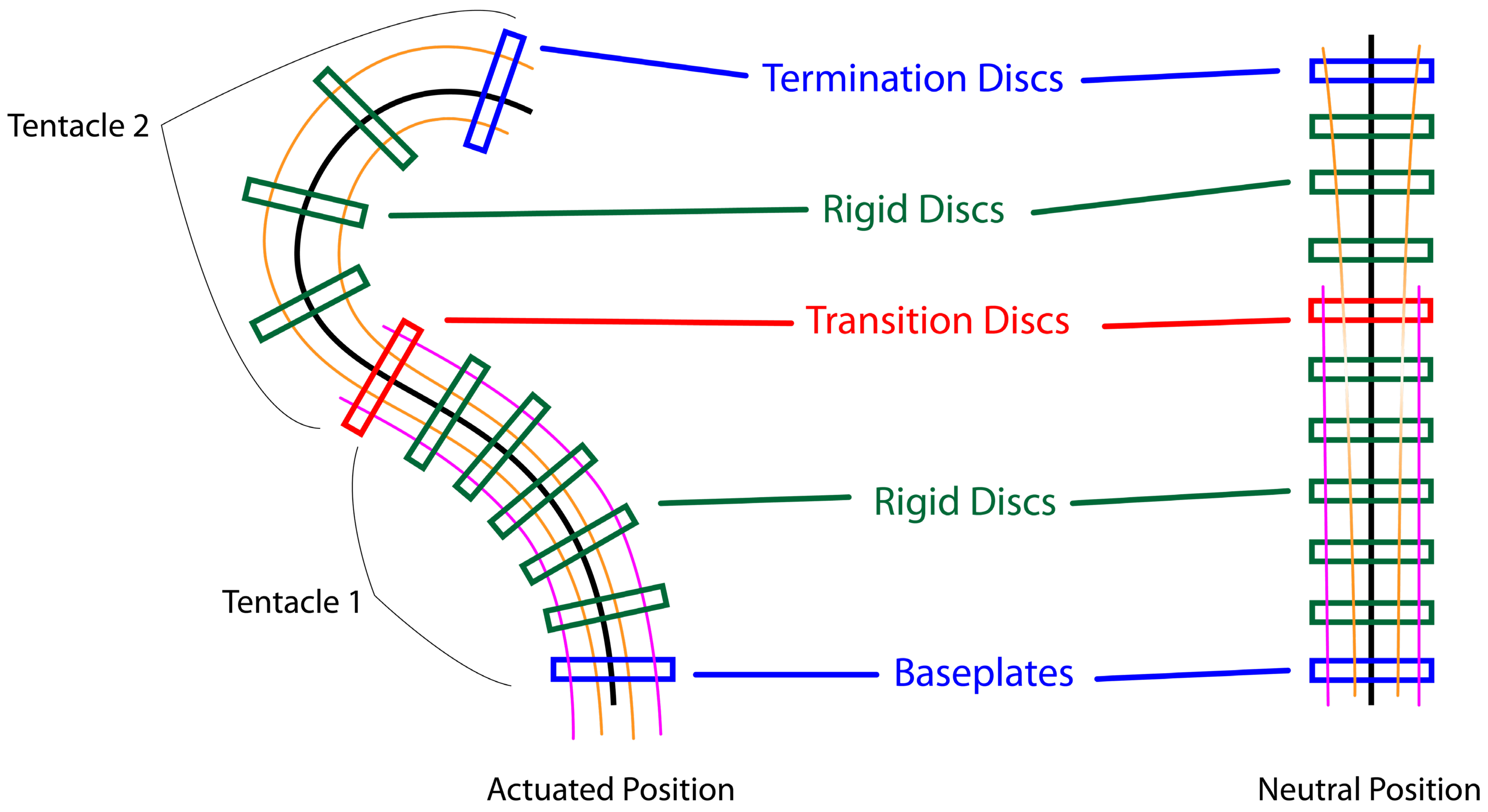








I went through numerous mechanical prototypes and different controllers for those prototypes. Mimicking different types of cable mechanism I saw within the special FX industry, I developed a prototype consisting of multiple flat discs that are attached to a flexible central shaft. Running through each of these discs are 4 cables that are linked to a controller mechanism.

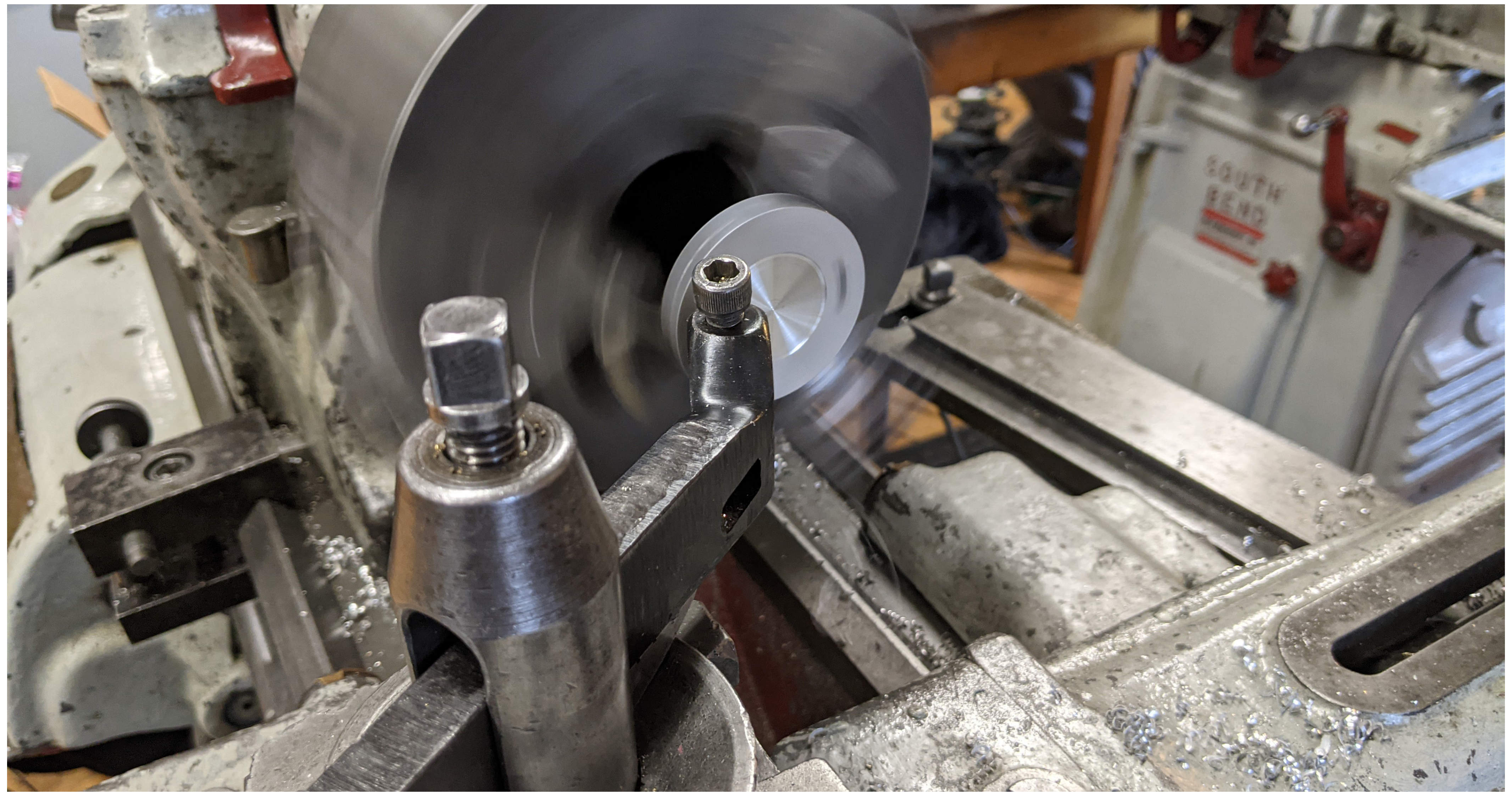
Single 4-Axis Tentacle Mechanism
Tentacle Diagram

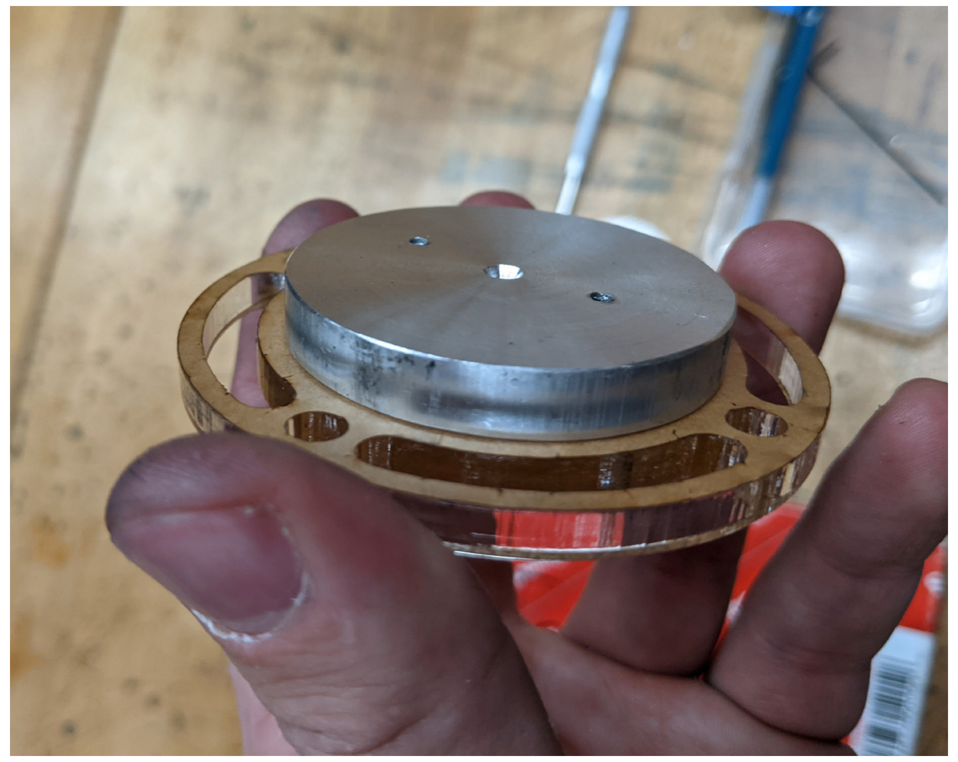


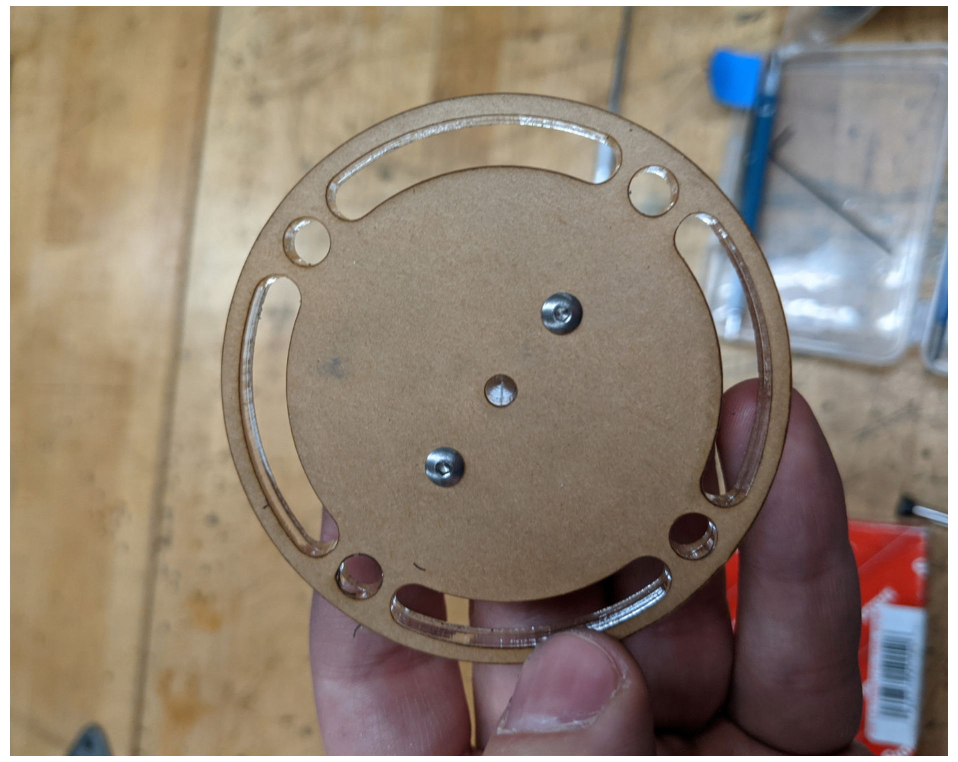
Compound 4-Axis Tentacle Mechansim
Tentacle Diagram

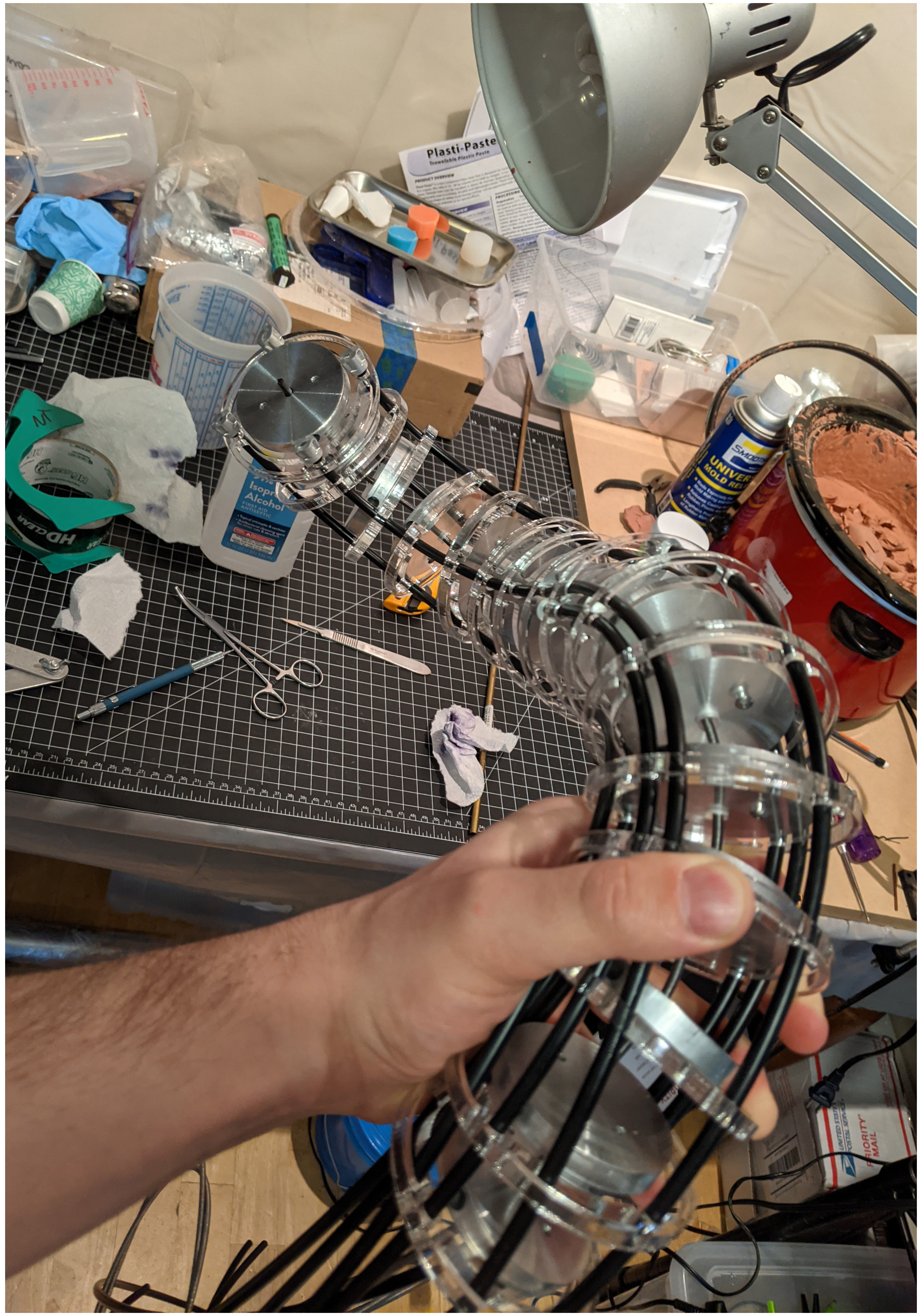


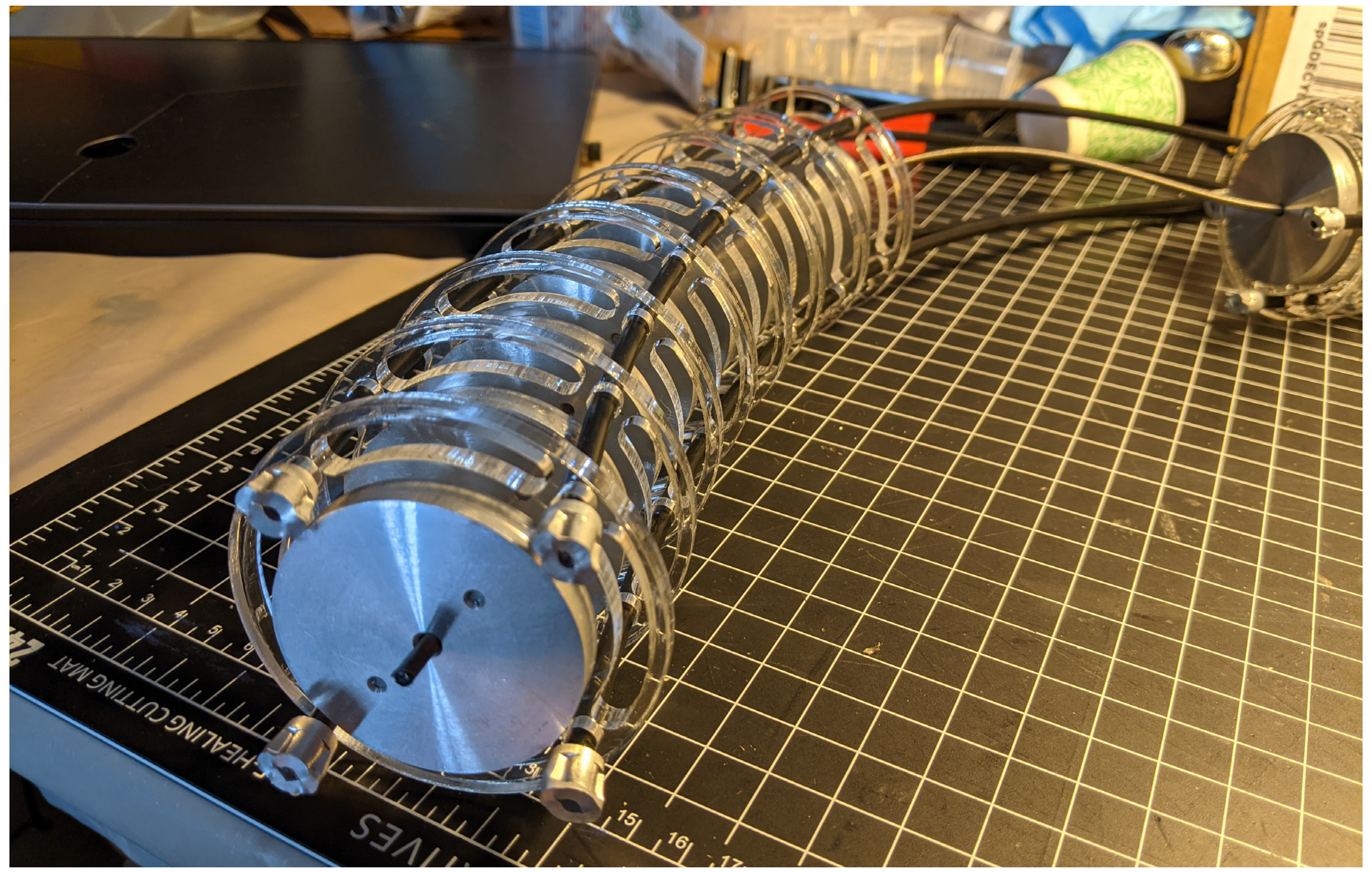
These two diagrams illustrate how each of my tentacle mechanisms work. The one on the left is an illustration of a single 4 axis tentacle like those seen in my early prototypes. The one on the right is an illustration of two 4 axis mechanisms attached together and is representative of the interactive tentacle mechanism that was made for the exhibition at the RISD Museum.

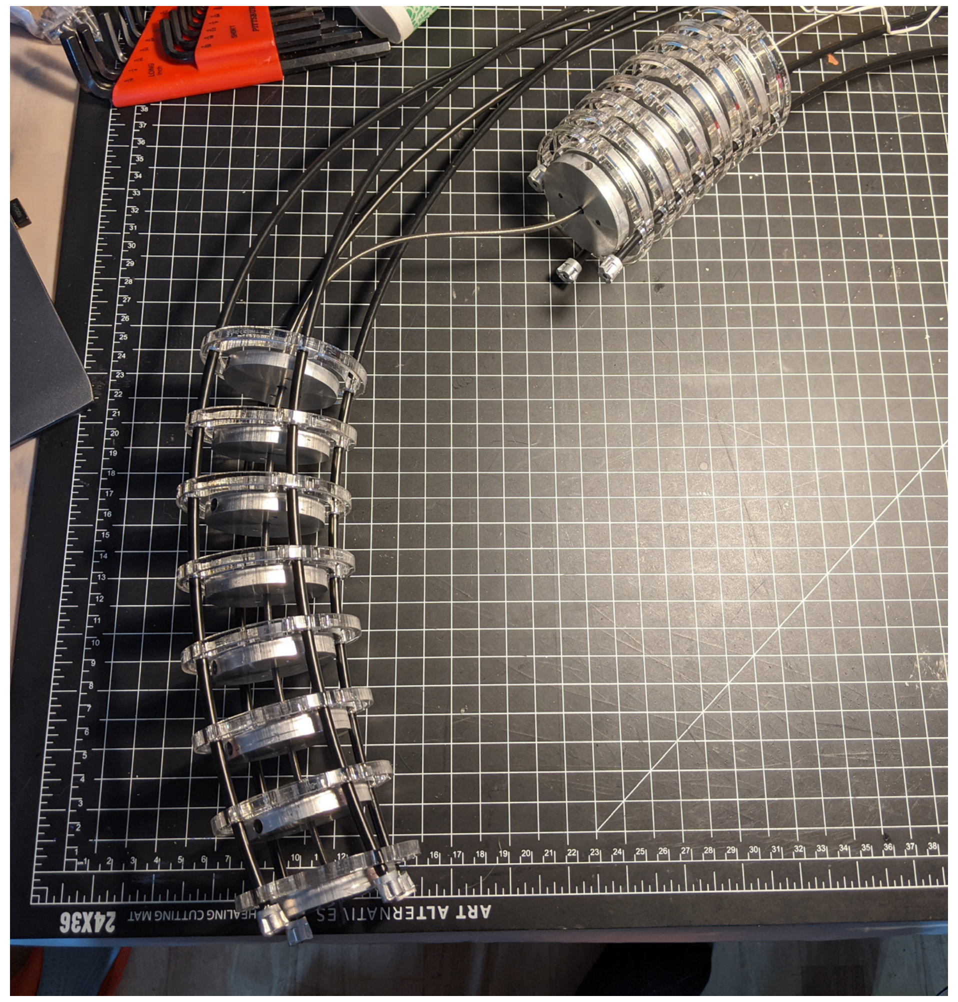










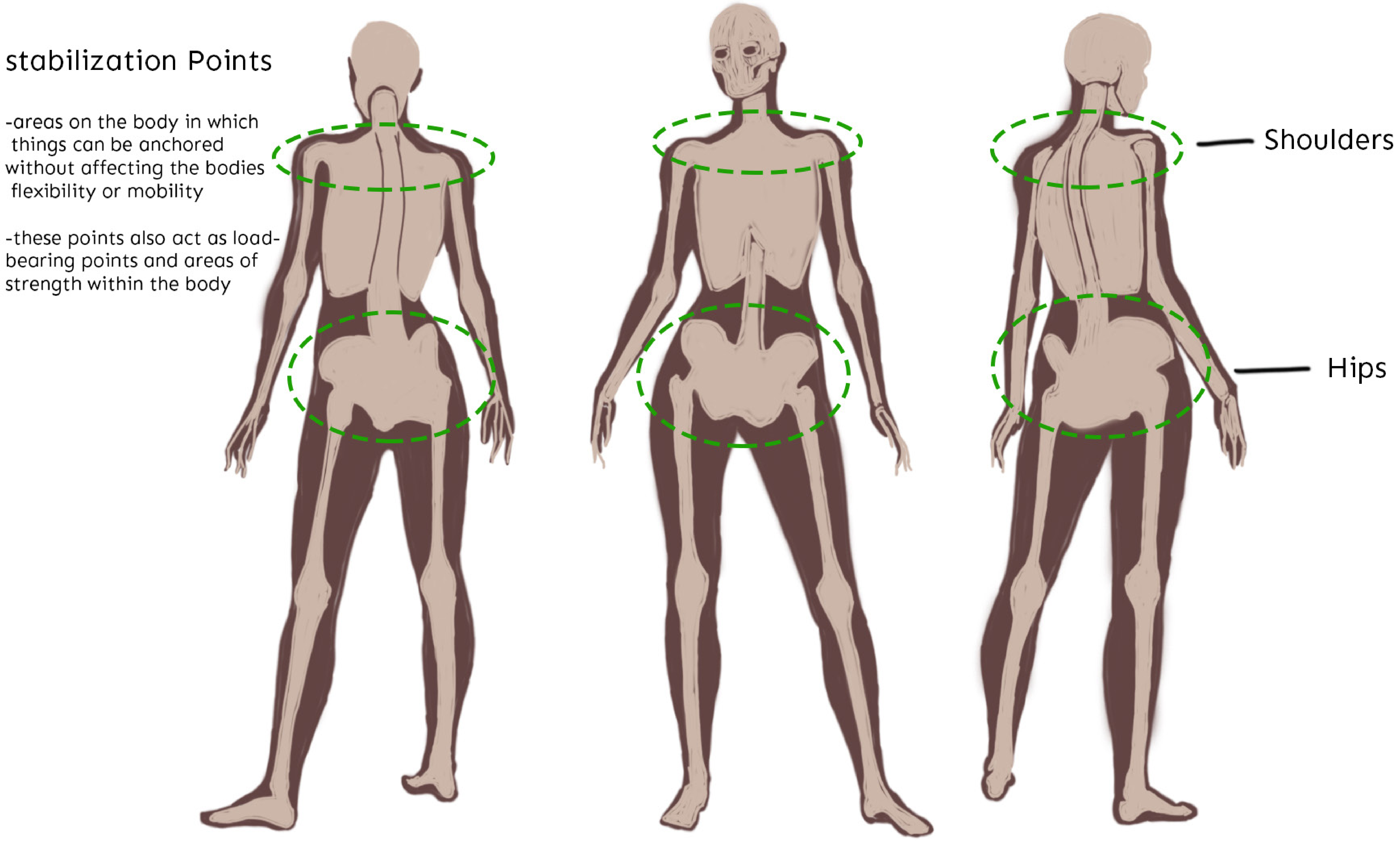


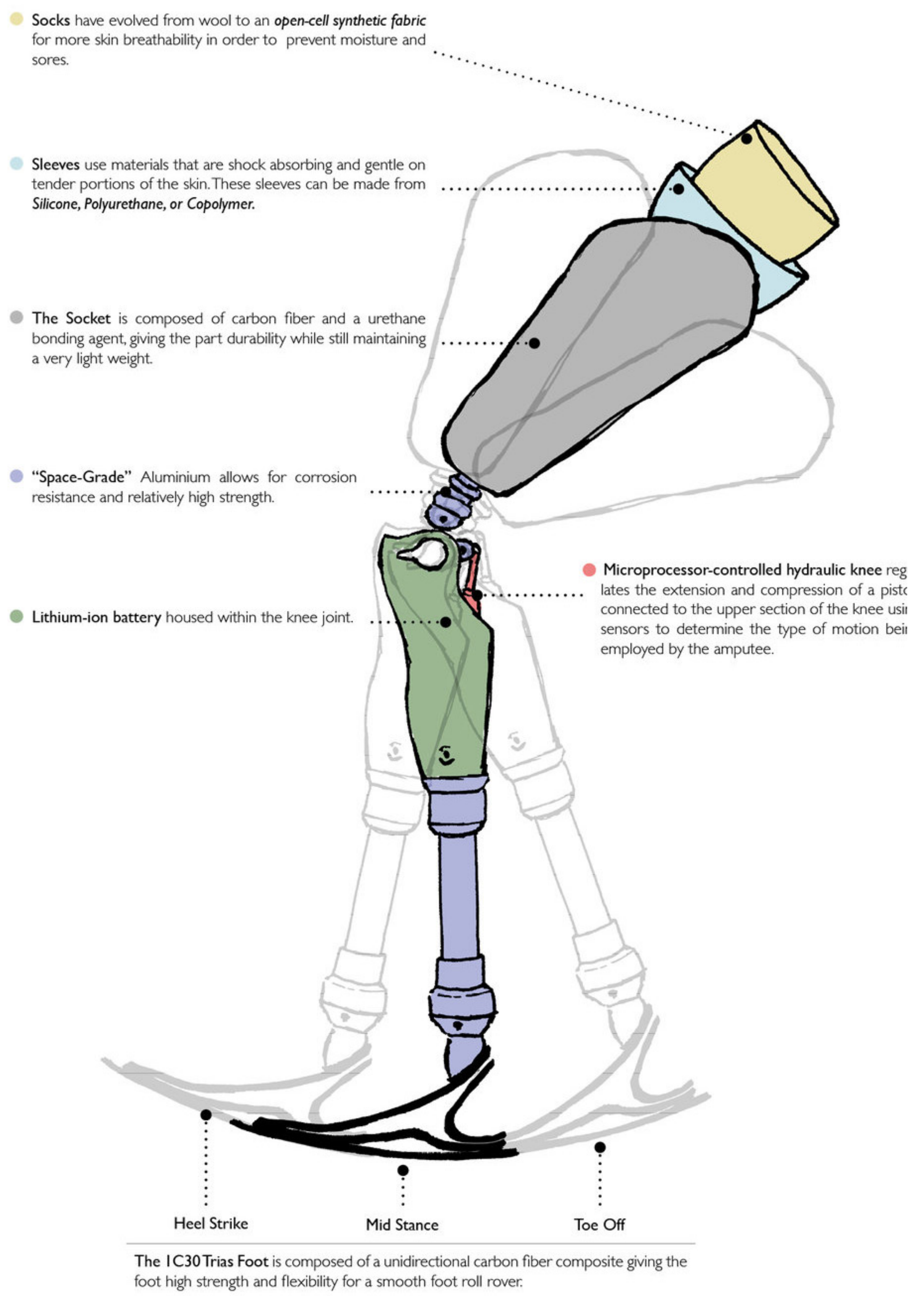
Development of the finished controller was done with a variety of materials including laser cut acrylic parts and machined aluminum components. The tentacle and the controllers were made for the use of people visiting the exhibition at the RISD Museum so they could experience what it was like to control a robotic tentacle mechanism.

Design for Supporting the Body

Building on the functionality and material constraints that I established for myself by exploring the different mechanical functions of the octopus, I began theorizing what form my extended body design would take. I knew that it would have to fit around the human body and that if it inhibited human functionality that it would ultimately be counterproductive to create. The intentionality of my design is one that is additive in the tasks and functions that it can perform and a design that inhibits a users range of motion or the use of their limbs would contradict this. To start, I began by looking at how things are rigged and attached to the body. This process involved analyzing and deconstructing a number of wearables and harness systems to identify not only how to attach a heavy form to the body securely, but also to identify anchor points on the body where my extended body design can extend from. Through this research I identified two distinct groups of designs that work around the body. Those that are bodily supporting and those that are supported by the body. Bodily supporting designs are those that quite literally support the user and are strong enough to support their body weight, examples of these include climbing harnesses and exoskeletons. Bodily supported designs on the other hand, require the user to support the weight of the design themselves and are much more common as they dont require as much support or power; examples of these include backpacks and any other wearable. This research also identified key areas of support and interconnection, these "stabilization points" are areas where more rigid designs could be placed while minimally impacting a users flexibility and range of motion. Since my design is striving to create new modes of movement and interaction, I chose to go with one that was bodily supporting as it would not be hampered by the limitations of the users individual strength in order to accommodate the design. I also prototyped multiple designs at scale around a couple of anatomical figures using wire and clay to visualize how different octopus extended body designs would look when orientated on different parts of the body. Of the two stabilization points that I could have orientated my design on, I chose to go with one oriented around the hips as it would allow the user to sit or rest comfortably into the design and would more naturally support their body. A design oriented around the shoulders,contrarily, would require additional support for the rest of the users body in order to accommodate and would likely be much less comfortable as it is requiring them to put all of their body weight on their shoulders and under their arms.

Two early designs looking at how an octopus based extended body would fit on and work around a user's body. These were sculpted out of clay using scaled anatomical figures as a base.

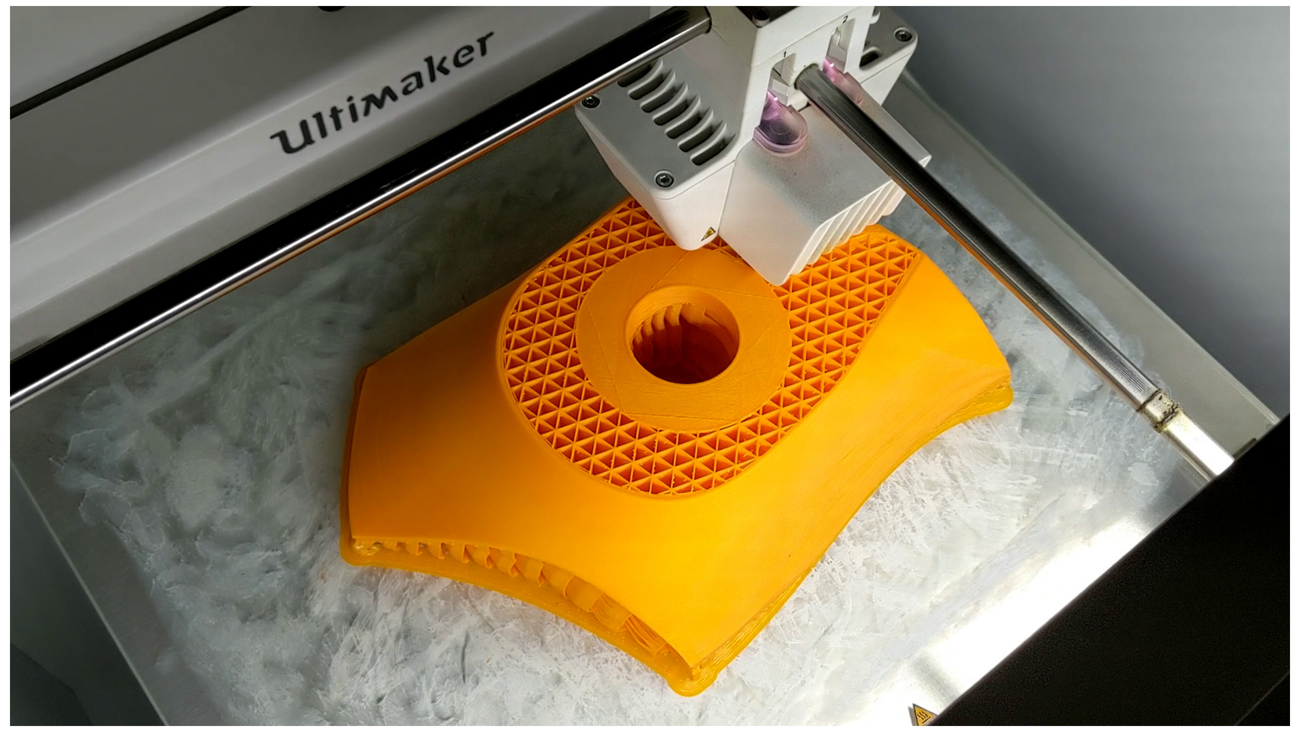




To inform how my design would conform to the body but still provide a strong and secure connection that could support the robotic mechanism, I had to look back at the design structure used in contemporary prosthetics. They face a similar design challenge with the implementation of their altered body designs as I do with my extended body designs. For strength and durability, most prosthetics, especially commercial prosthetics, are made out of rigid materials. These materials do not intersect well with the soft human body. Additionally, the point at which an users' residual limb intersects the design changes from person to person. To overcome this, an intermediary material is used. In most cases it is a soft flexible material, like silicon, that conforms to the user's body and shapes it so that it can more readily intersect the design of the prosthetic. Essentially, it is a silicon sleeve that "fills the gap" between the user's body and the design. I took a similar approach when addressing the gap between my design and the human body and incorporated a soft silicon undersuit that the user would wear while interfacing with the design.

Left:
A simple diagram outlining areas on the body that are best suited for supporting external designs as well as being supported by external designs.

Right:
A diagram that deconstructs a sample prosthetic into its individual parts. Note the use of a silicon sleeve that acts as an intermediary between the prosthetic and the users' body.



These images showcase the development of a partial visual prototype so that users can see the section of the octopus extended body that intersects with the body. This process involved a material exploration to identify the right type of silicon for constructing the under-suit as well as the fabrication and assembly of a sectional of the octopus extended to go on display in the RISD Museum.

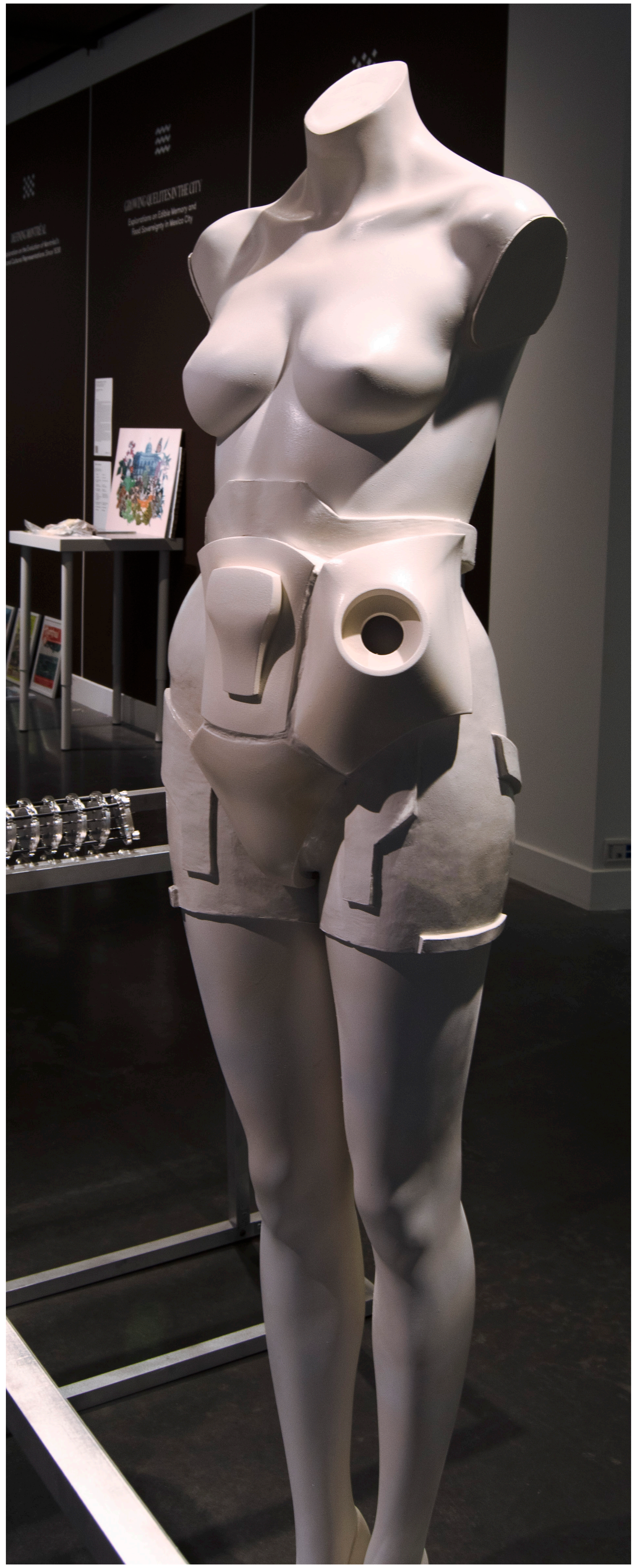
DEFINING AESTHETIC CHOICES

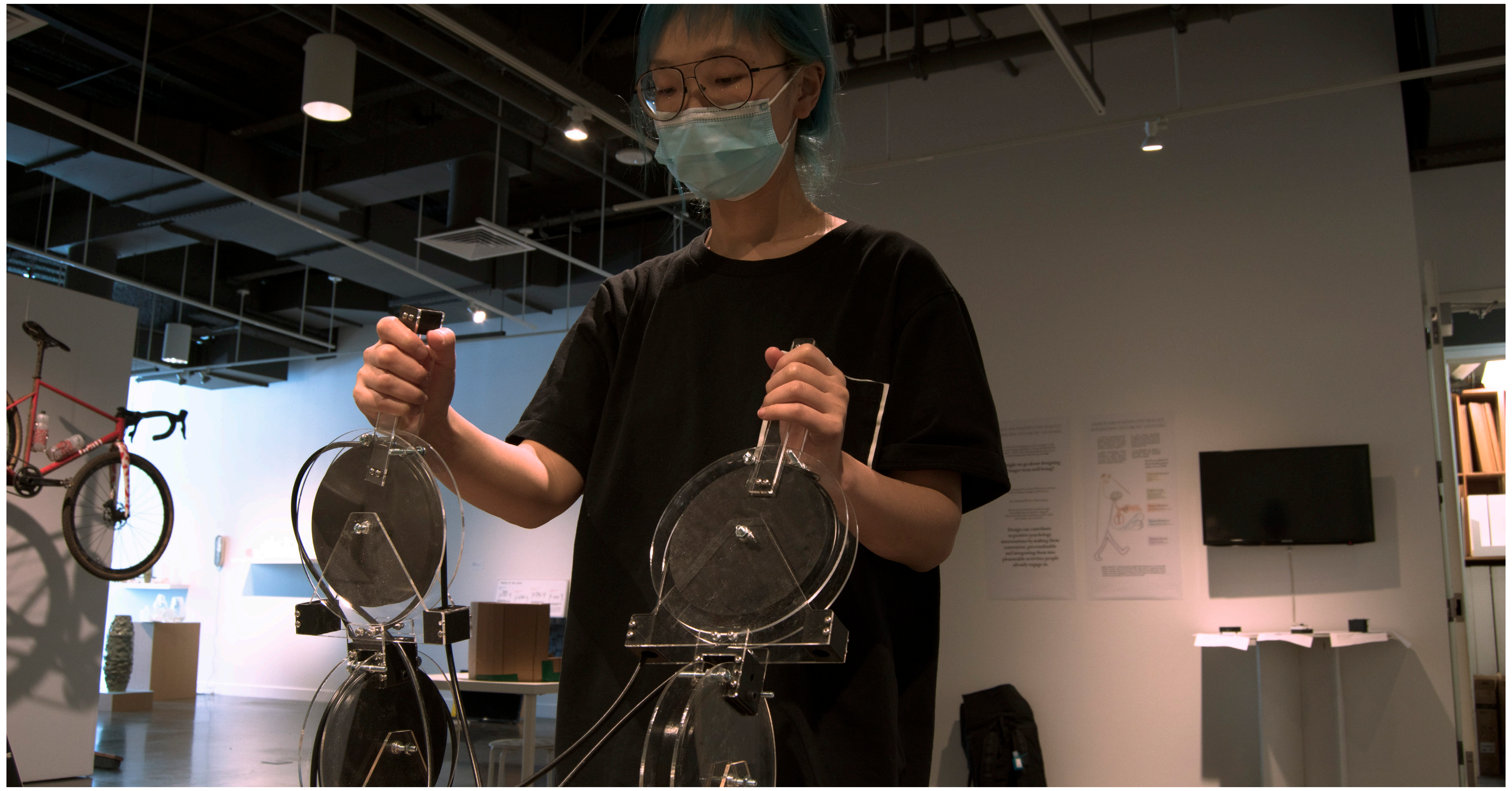
For informing the aesthetics of the design itself I again returned to my specimen the giant pacific octopus. I think that it is important to highlight that the creature inspiring my design, the giant pacific octopus, has the highest variation of color and texture in its chromatophores in comparison to any other cephalopod species including other octopus species. They have no true resting state, and even when dead, their chromatophores typically retain the color and texture of their latest environment. But within a vacuum, their bodies are blank slates which is a reflection of their physiology as without an environment or activity to ground them in, the octopus appearance and behavior is quite innocuous and inert. This is contrary to how we often view them within their native aquatic and semi-aquatic environments; but it is just this contrast that highlights their versatility and adaptability. The octopus, in its neutral state also offers multiple avenues of biological exploration in and of itself and I am only exploring a few of those with this design. Likewise, my design based on the octopus offers multiple avenues of approach by the mere presentation of possibilities within a consolidated form, but it doesn't make preconceptions on what to do with those forms by suggesting a specified activity, mode of use, or by adopting a particular design aesthetic for a specified user group. This also allows the design to be more conducive to creating dialogues with people across different industries and more successful-ly conveys my intended goal of conceptual exploration. This would not have been possible If i had made the design hyper specialized for a particular use. An example of this could be, that if the design is informed by a military aesthetic (color, forms, materials) then that would preclude a military use for the design and military users for the design which would exclude other narrative or theoretical possibilities. This would likewise be a problem if I adopted any other specific aesthetic, therefore, in order to leave the potential open and to demonstrate the multifunctionality of the design and let viewers imprint their own potential direction and uses for those functions, what I am presenting is a centrist perspective. I want to emphasize that this does not mean that the design does not have any specific uses or specific users, only that if I presented very specific uses for a very specific user group it would narrow the potential for the design and muddle its intended purpose.

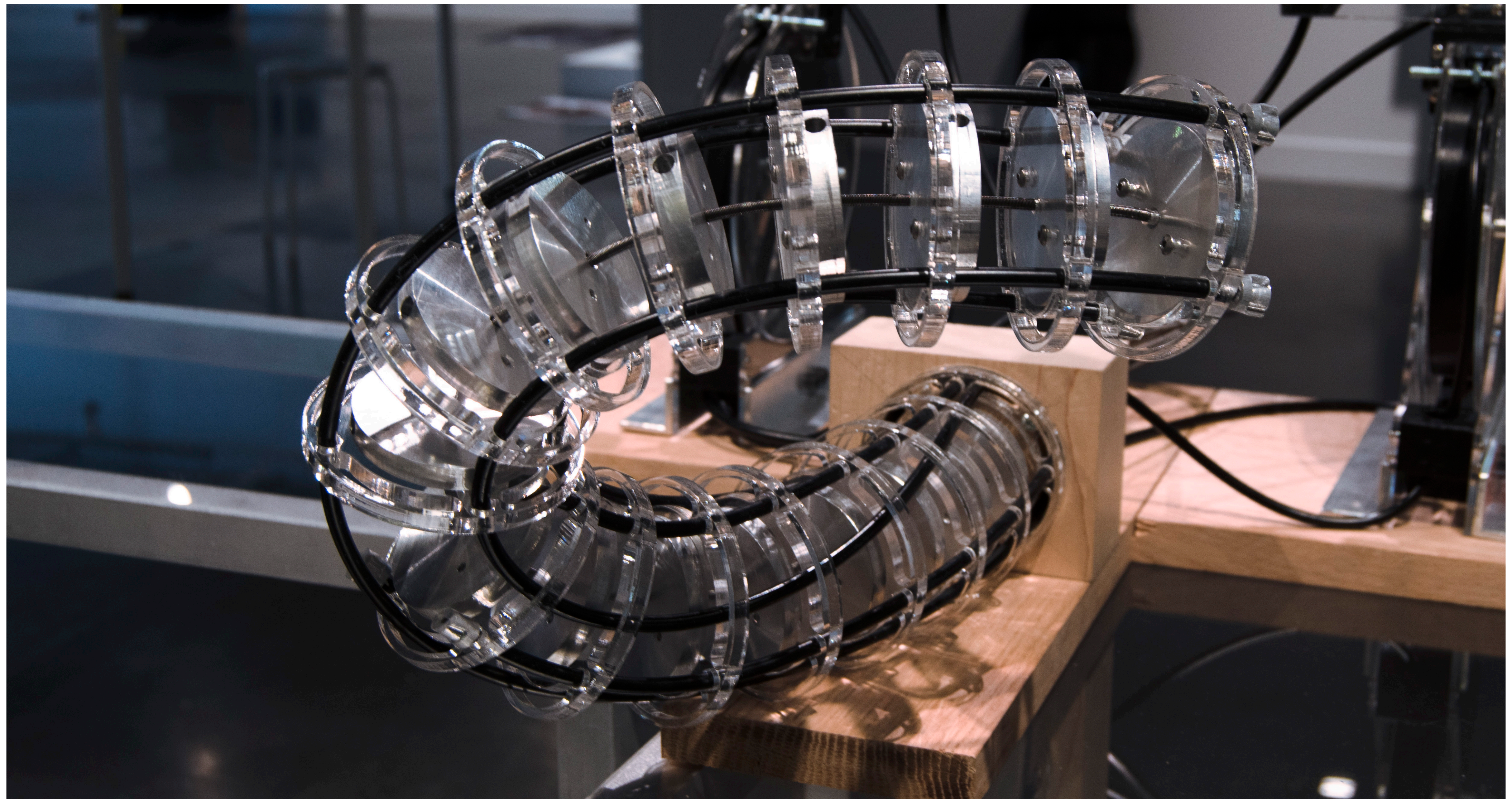
Aesthetics of the octopus transforming between different colors (3 photos?)
These photos depict a captured octopus rapidly changing the color and texture of its skin in response to its new environment. This process is instinctual and happens independently of the octopus' own will. Qualities like this are yet another reason why I chose the octopus, because its physiology lends itself to adaptable self expression and change.

EXHIBITION

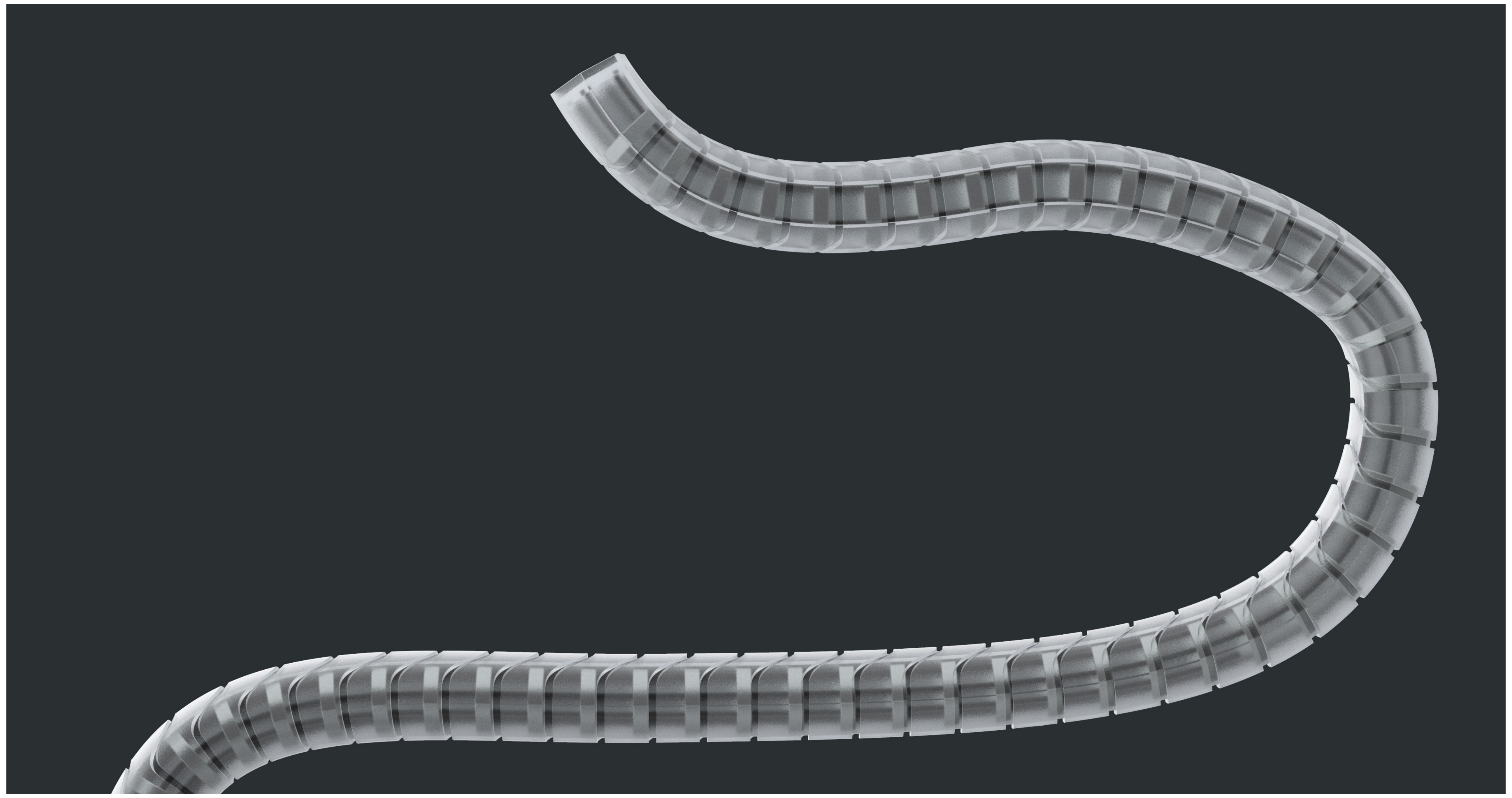
These are photos from the 2021 Masters of Industrial Design Thesis Exhibition at the RISD Museum. The exhibit includes a partial model showing the wearable section of my octopus extended body attached to a female mannequin form. Surrounding it are two tables. On one, is an interactive two stage tentacle mechanism that allows visitors to the exhibition to experience how my mechanical facsimile of the octopus' tentacle would work. Each controller allows the user to control a different end of the tentacle, each of which have 4 axis of motion similar to my previous mechanical prototypes. The other table has a monitor that informs the user about the designs development, intentions, and potential modes of use.

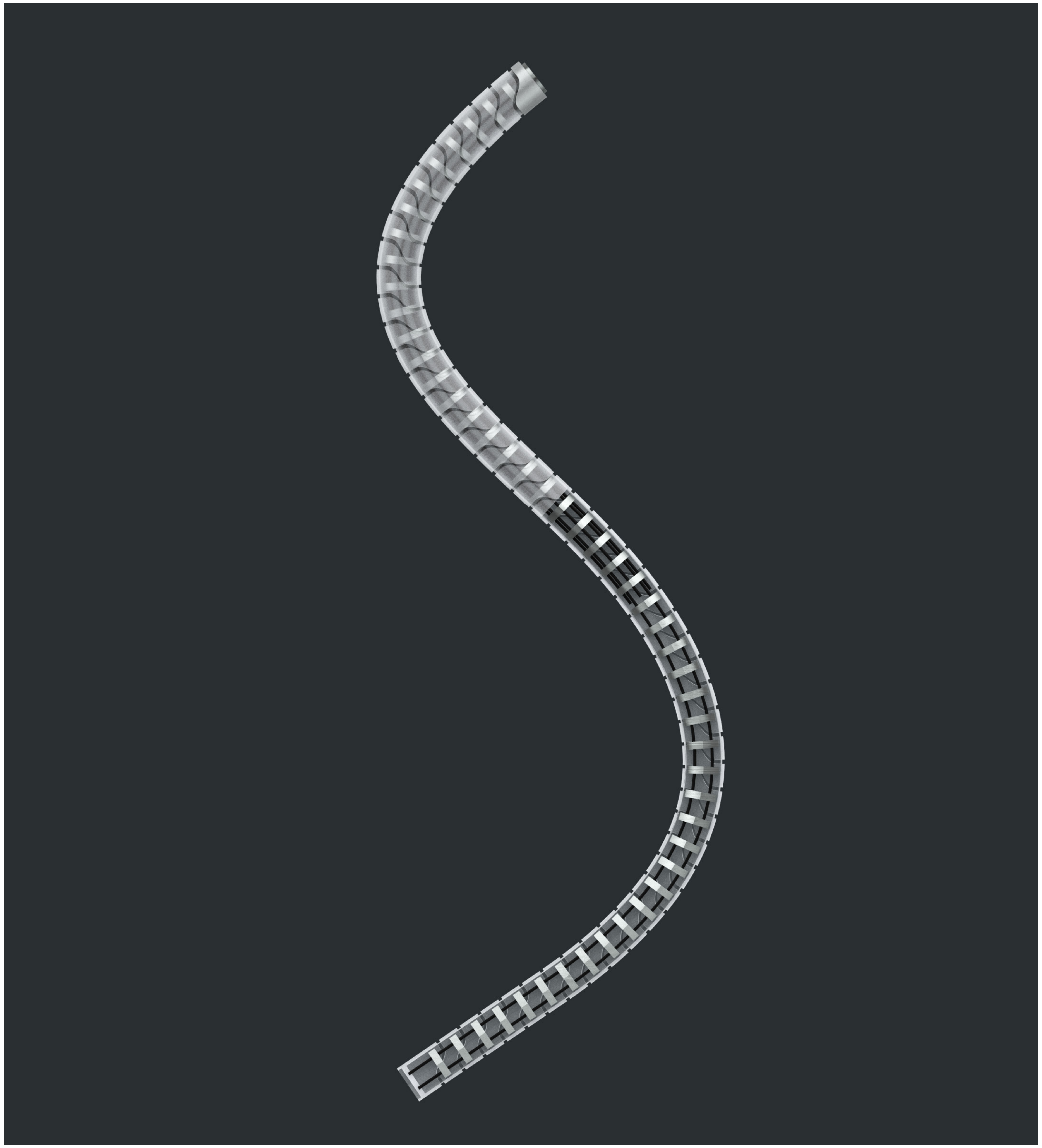


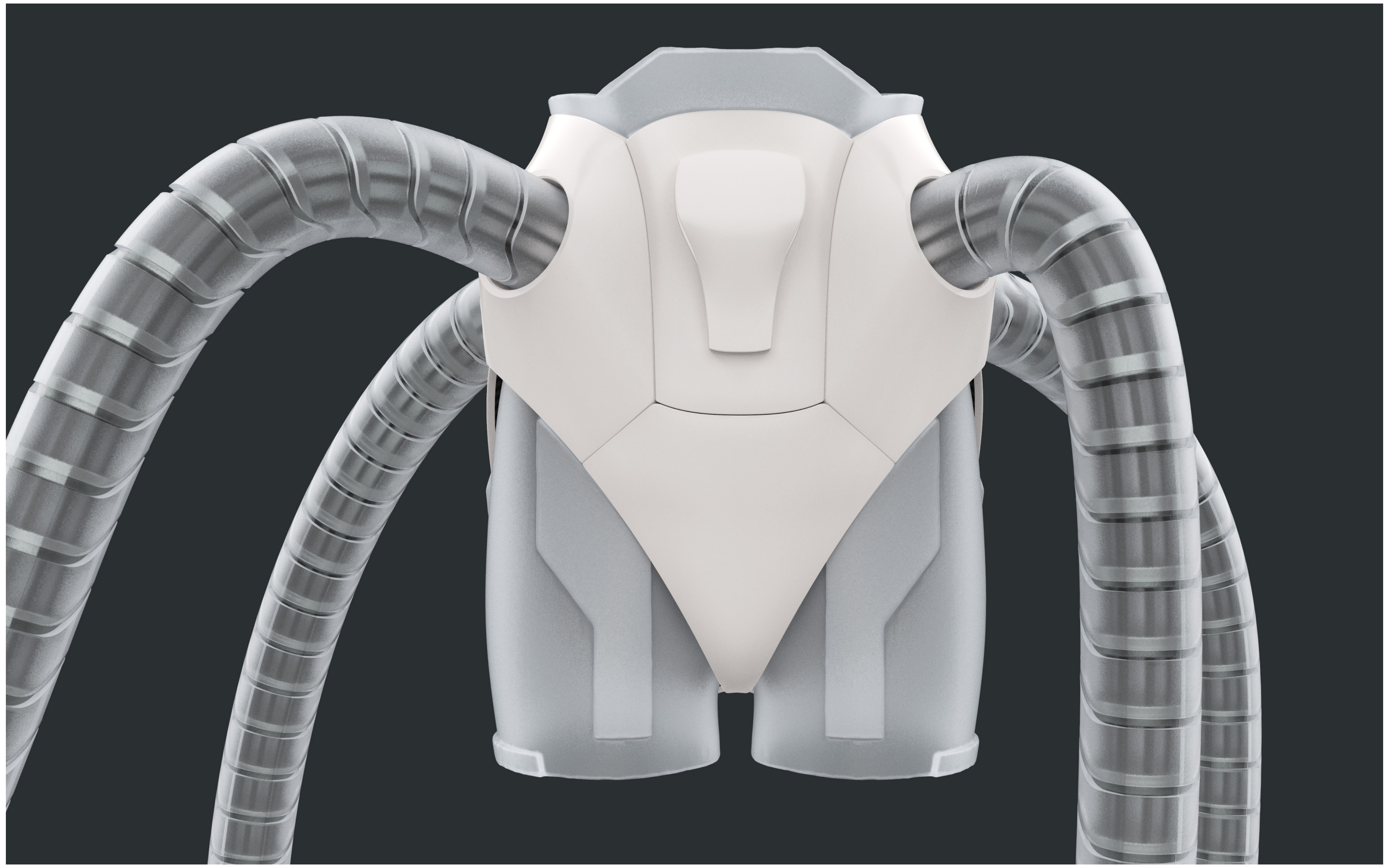


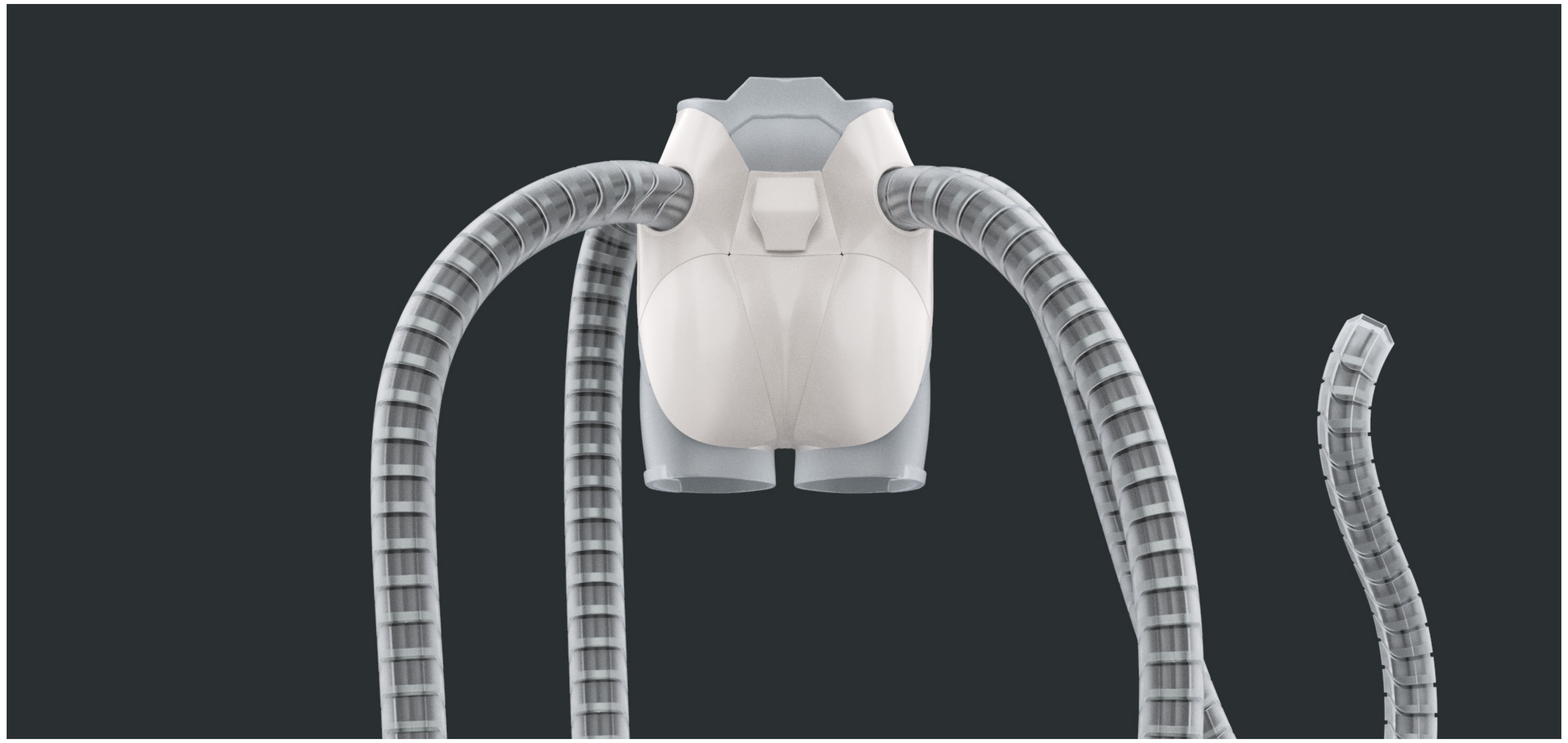


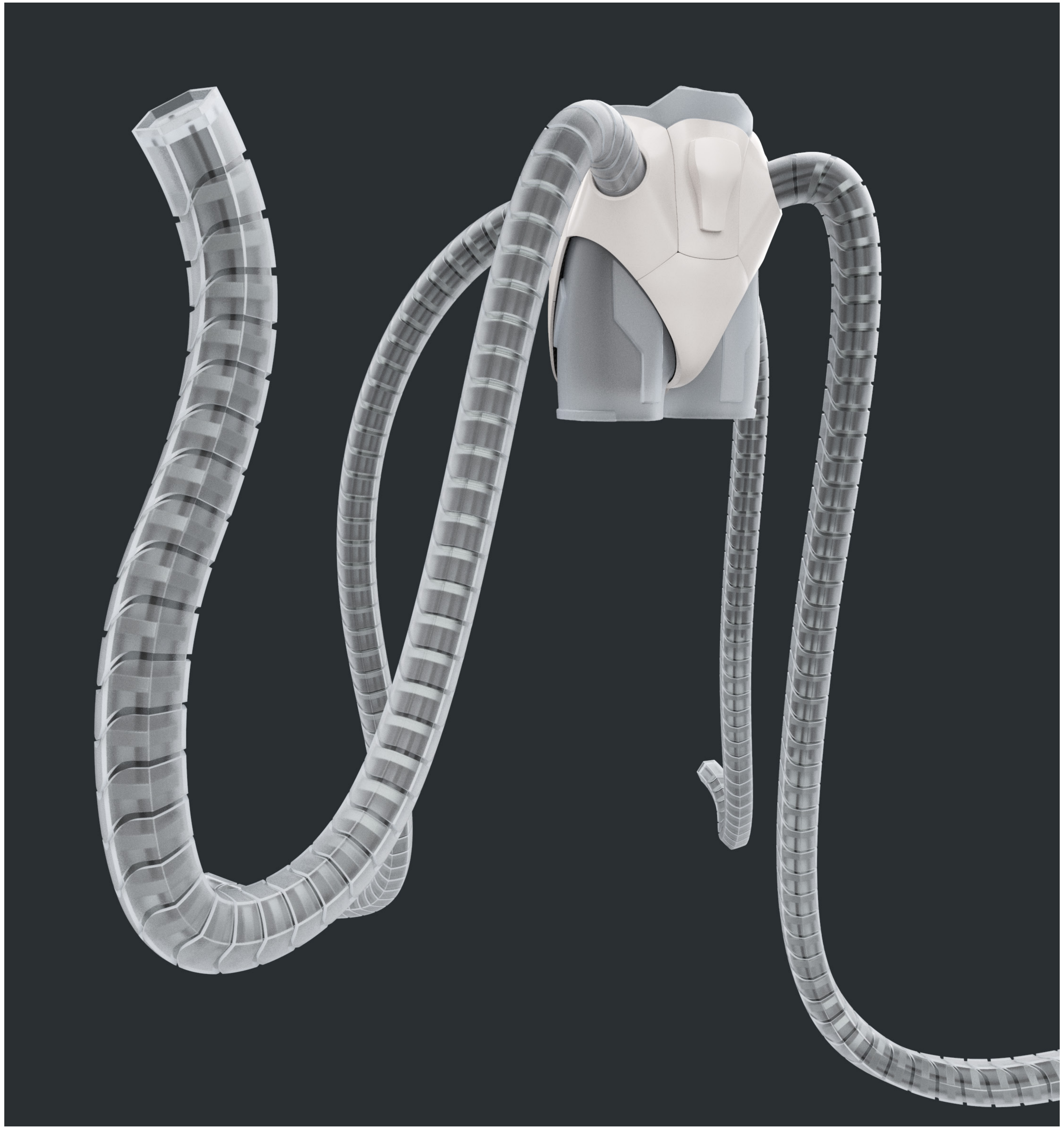
These final renderings represent how I envision a fully functional version of my design looking as well as the ideal material choices for each section of the design. The tentacle mechanisms consist of two distinct parts. An internal mechanical section composed of rigid discs that are fixed to a flexible central core. Like the interactive prototype that I made for the exhibition, these discs are activated via the use of cables running through all of the discs in the tentacle. The pulleys for these cables are located in the core of the design situated around a potential user's waist. These rigid mechanical parts are surrounded by a soft silicon sleeve turning the tentacles into a hybrid design of mechanical and soft robotics. The wearable section of the design consists of two parts as well. A soft silicon undersuit that conforms to the user's body acts as the transition layer between the user and the rest of the design. On top of the undersuit is the rigid shell of the design. This part houses all the additional computers for controlling the tentacles as well as a link to the users implanted BCI for operating the tentacles, the batteries (located on the rear compartment) for powering the design, the cable pulleys, and the various other electronic components necessary for the design to function.

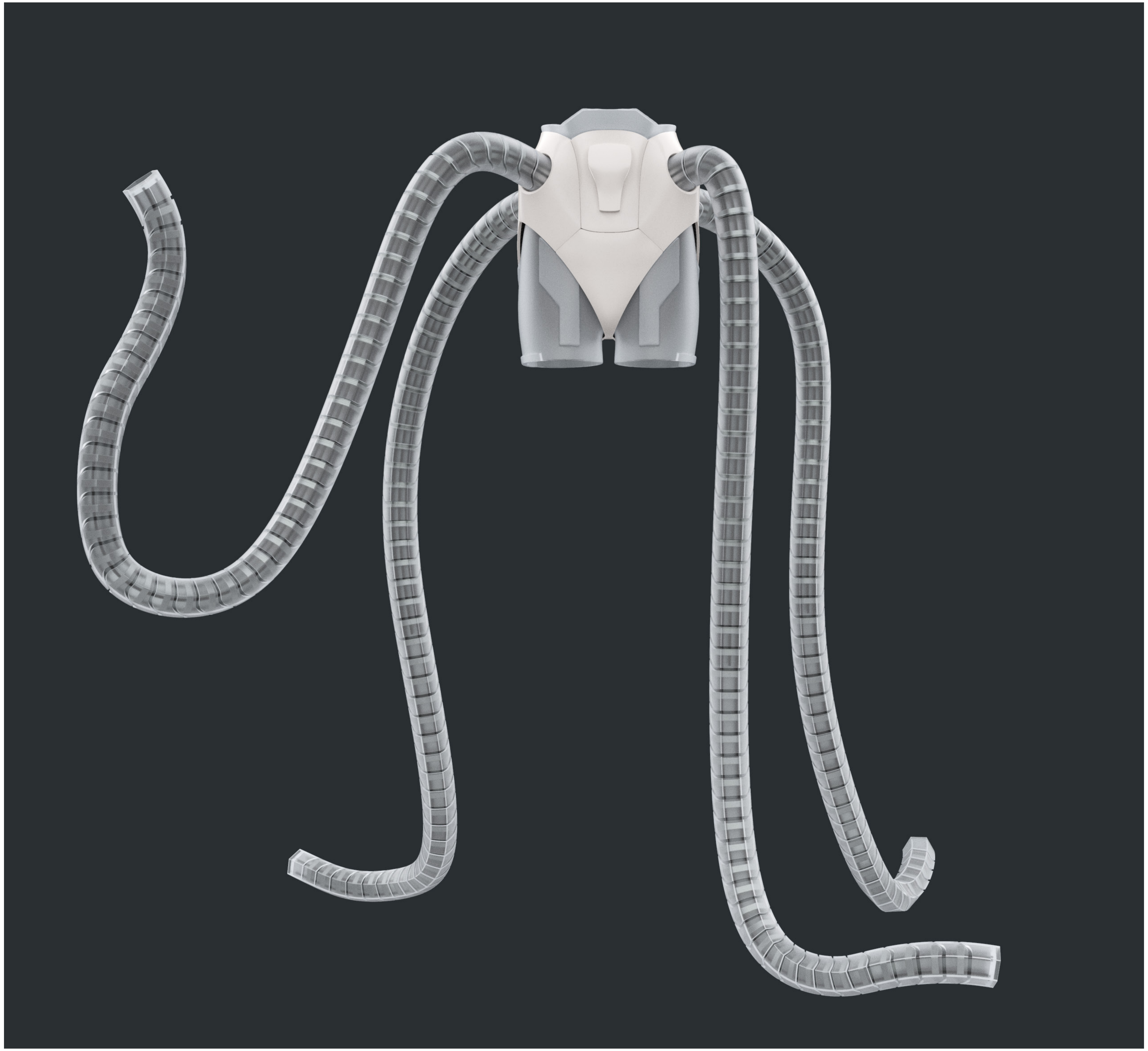


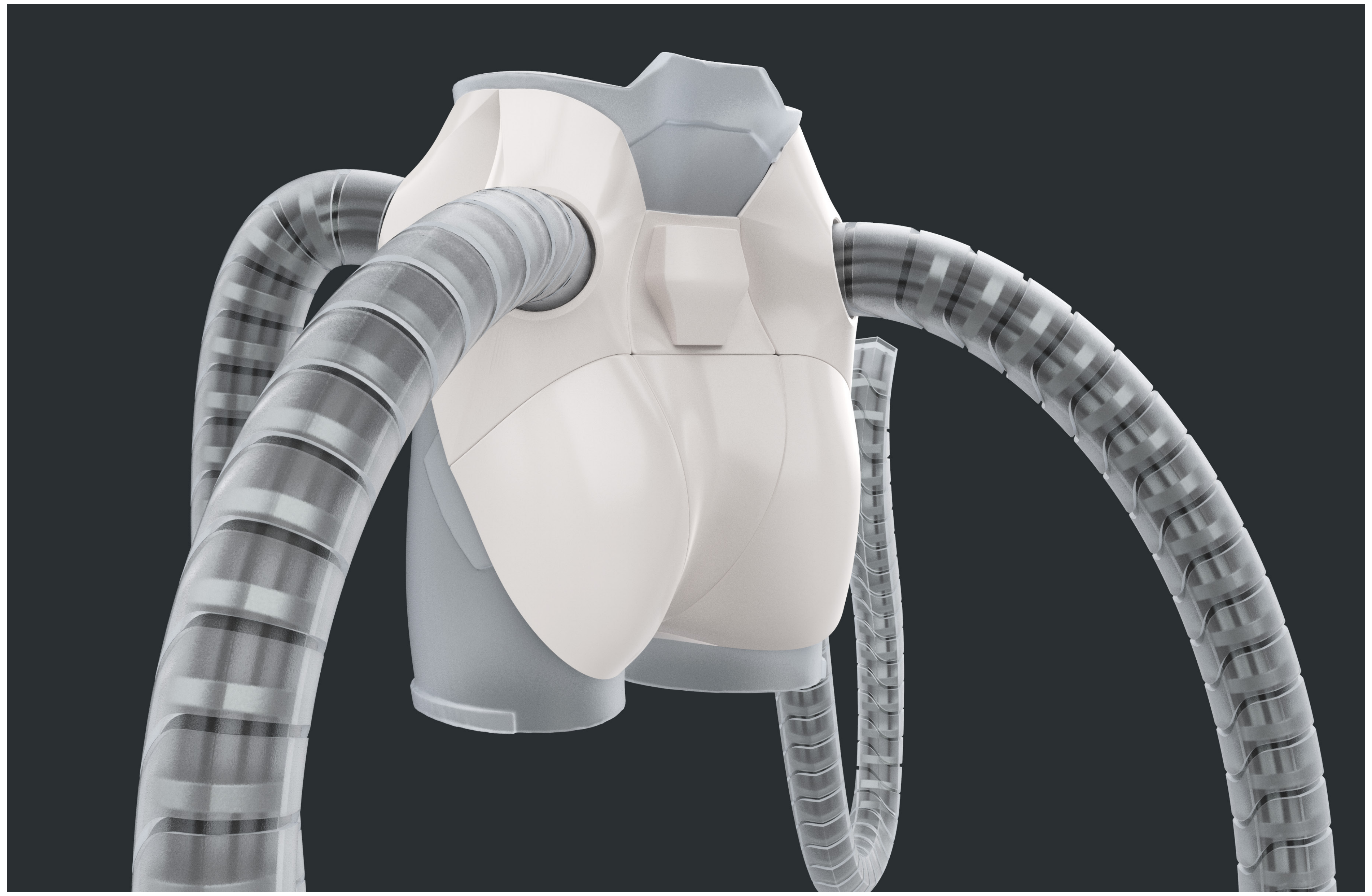


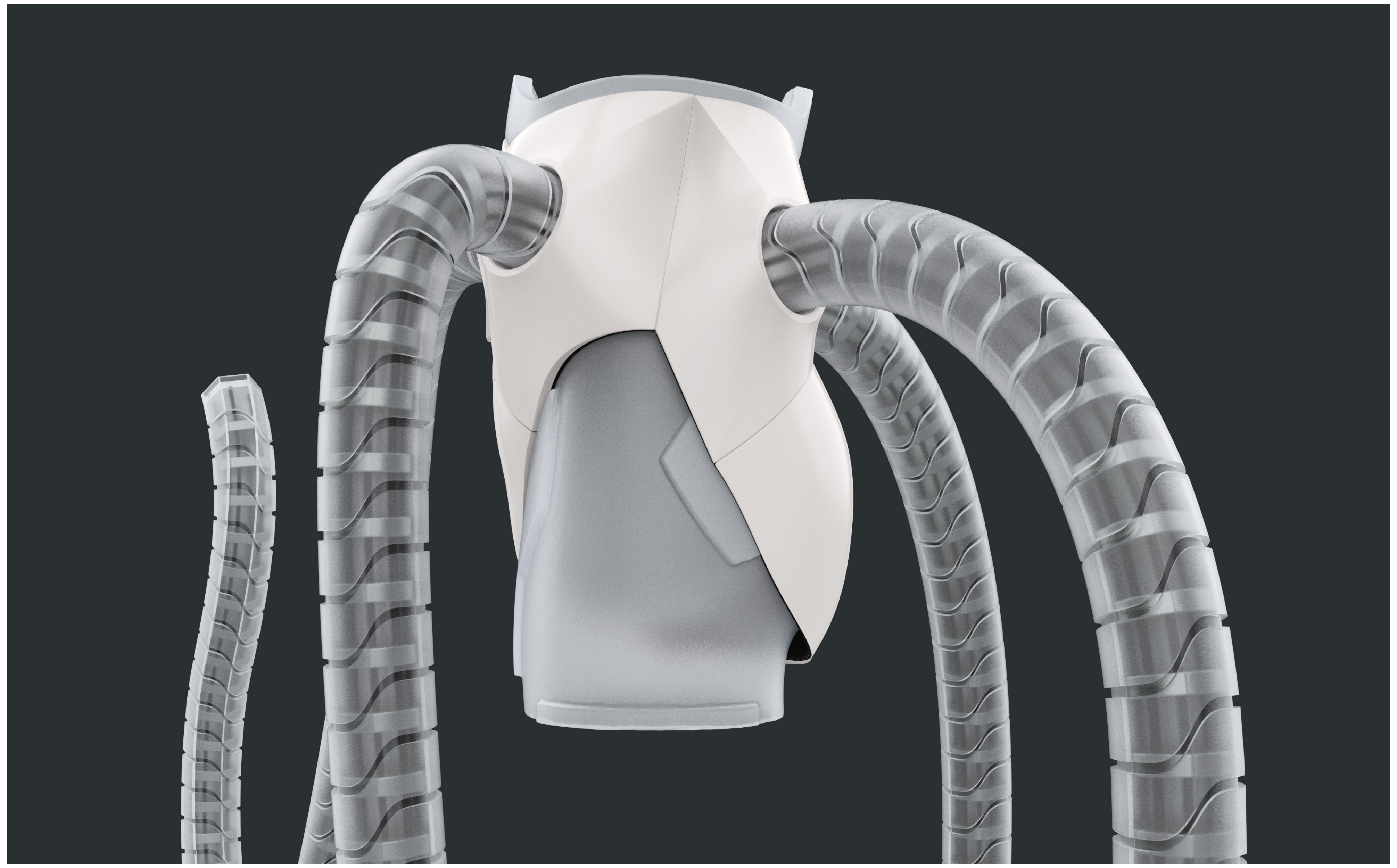












BIBLIOGRAPHY

“Aimee Mullins.” Women’s Sports Foundation. 02 Oct. 2019. Web. 28 May 2021.

“Borton Lab - Projects.” Web. 28 May 2021.

“CRISPR Pioneer Jennifer Doudna Headlines NHGRI 25th Anniversary Celebration.” National Institutes of Health. U.S. Department of Health and Human Services, 16 Oct. 2018. Web. 28 May 2021.

Dick, Phillip K. The Android and the Human. Vancouver: University of British Columbia, Mar. 1972. Pdf.

Festo. “Products.” Products | Festo USA. Web. 28 May 2021.

Haraway, Donna Jeanne. Simians, Cyborgs, and Women: The Reinvention of Nature. Routledge, 2010. Print.

Herbert, Frank. Dune, Book One. Ace, 1987. Print.

“Historical Results Database.” IPC | International Paralympic Committee Sports & News. Web. 28 May 2021.

Https://borton.engin.brown.edu/images/projects/braincell/braincell-1.jpg. 28 May 2021.

Https://borton.engin.brown.edu/images/projects/neurofilm/LBL.jpg. 28 May 2021.

Https://i.natgeofe.com/k/46655f11-9522-411d-9e3b-1a6a576cb0c8/octopus.jpg. 28 May 2021.

Https://i.natgeofe.com/n/622db4d3-6f73-462d-b08f-4fb528467f50/01-flamingo-friendships-nationalgeographic_1477297.jpg. 28 May 2021.

Https://i.pinimg.com/originals/98/bb/aa/98bbaa5a7d5cbace7863d6b82a2b05cb.jpg. 28 May 2021.

Https://i.pinimg.com/originals/b5/06/88/b506884d75b3cac1c1d9684f8757ae5f.jpg. 28 May 2021.

Https://i.ytimg.com/vi/7mokPWCTPZY/maxresdefault.jpg. 28 May 2021.

Https://images-na.ssl-images-amazon.com/images/I/81HuJlx2MwL.jpg. 28 May 2021.

Https://images.squarespace-cdn.com/content/v1/56376cfde4b078ea32822fff/1509111174057-FG9VNV0T3RC13ELDHBDB/ke17ZwdGBToddI8pDm48kG4VqDreF-qTqyP-RyQBlzwUqsxRUqqbr1mOJYKfIPR7LoDQ9mXPOjoJoqy81S2I8N_N4V1vU-b5AoIIIbLZhVYxCRW4BPu10St3TBAUQYVKcYFaooDpJDzwXGThQ4lumDwueSgDRAovwNJvlk7h3IELIXXgb5H6FFq1pCoZUfrM8/Tilly+-+hand+in+hand.jpg?format=1000w. 28 May 2021.

Https://images.theconversation.com/files/164279/original/image-20170406-6391-64023x.jpg?ixlib=rb-1.1.0&q=45&auto=format&w=1200&h=900.0&fit=crop. 28 May 2021.

Https://irp.nih.gov/sites/default/files/uploads/blog2/Doudna%20Image%202.jpg. 28 May 2021.

Https://lp-cms-production.imgix.net/image_browser/cheetah-built-for-speed.jpg. 28 May 2021.

Https://netdna.coolthings.com/wp-content/uploads/2015/03/flexshapegripper-3.jpg. 05 May 2021.

Https://static.designboom.com/wp-content/uploads/2014/03/festo-bionic-handling-assistant-designboom08.jpg. 28 May 2021.

Https://upload.wikimedia.org/wikipedia/commons/d/de/Tree_of_life_by_Haeckel.jpg. 28 May 2021.

Https://www.festo.com/media/cms/central/media/editorial/img/cc/bionics-bionics4education-01873-festo_w1320.jpg. 28 May 2021.

Https://www.hortonsoandp.com/the-parts-of-a-prosthetic-leg/. 28 May 2021.

Metzl, Jamie. Hacking Darwin: Genetic Engineering and the Future of Humanity. Source, 2020. Print.

My Octopus Teacher. Dir. Pippa Ehrlich and James Reed. Netflix. Web. 28 May 2021.

“Person Overview ‘ Hugh Herr.” MIT Media Lab. Web. 28 May 2021.

Thwaites, Thomas. GoatMan: How I Took a Holiday from Being Human. Princeton Architectural, 2016. Print.

“Turning Disabilities into Superpowers.” Open Bionics. 27 May 2021. Web. 28 May 2021.