Introduction

Modulus is a speculative design project that explores possible trajectories in the fields of bioethics, biomimicry, synthetic biology, and genetic modification under the framework of morphological freedom. We believe that a link to preferable futures can be made with the act of redefining self-expression; the ability to engineer one’s identity through body augmentation is one of the many ways humanity can level the playing field amongst themselves and elevate it further to prompt significant societal advancement. Humans are typically stratified by their abilities and their performance regardless of their access to opportunities for self-improvement—in an imagined world where designing one’s capabilities is feasible, affordable, and bound by merit and fundamental right rather than influence and financial means, there should be no more widening gaps between the privileged and the disadvantaged. In a world such as this one, challenging the limits we impose on innovating the fields mentioned above is a crucial start to initiating discourse.

In this paper, we explored potential feasible human enhancements and researched current scientific trends and experiments that could lead to them. Additionally, we delved into the morality and challenges presented by augmentations and modifications such as gene engineering, and discussed the prospects and ramifications that human alteration could have on our current societal framework. This was done in an attempt to give some plausible answers and insight on future cultural shifts and legislative changes.
Discussion

1. History and science behind synthetic blood at Modulus

William Harvey first described the circulation of blood in 1616. The first modern efforts to produce artificial blood were spurred on by the military in World Wars I and II, followed closely by the discovery in the early 1980s that HIV could be transmitted by blood transfusion.

At first, artificial blood was only designed to reproduce one of the many functions regular blood has: carrying oxygen and carbon dioxide.

However, blood performs many important functions within the body, including:

- Supplying oxygen to tissues (bound to hemoglobin, carried by red blood cells)
- Supplying nutrients such as glucose, amino acids, and fatty acids (dissolved in the blood or bound to plasma proteins (e.g., blood lipids))
- Removing waste such as carbon dioxide, urea, and lactic acid
- Immunological functions, including circulation of white blood cells, and detection of foreign material by antibodies
- Coagulation, the response to a broken blood vessel, the conversion of blood from a liquid to a semisolid gel to stop bleeding
- Messenger functions, including the transport of hormones and the signaling of tissue damage
- Regulation of core body temperature
- Hydraulic functions

At Modulus, we have created synthetic blood that is capable of carrying more oxygen than regular blood, but also improves on many other core functions.

Our new blood is engineered to clot much faster than natural human blood, but is also designed to continuously monitor a person’s arteries and keep them free of plaque, thus preventing heart attacks. In normal situations, bleeding causes a biological "domino effect" in which a series of steps are set in motion. When your body detects a bleed, the clotting factors are switched on in a particular order, one after the other, and tiny cells in the blood called platelets stick together around the wound to patch the leak. Blood proteins and platelets come together and form what is known as a fibrin clot. The clot acts like a mesh to stop the bleeding. This means that previously, if and when certain blood-clotting factors were deficient or missing in a person with a bleeding disorder, the blood would not clot as it should, and it took longer for a clot to form and for bleeding to stop. Now, with our specially engineered synthetic blood, the coagulation cascade is always guaranteed to work properly thanks to engineered nanoparticles [1].
We have also worked on developing synthetic white blood cells. These cells can be programmed from the outside, and receive data allowing them to adapt in order to fight a variety of threats, such as new infections or a specific kind of cancer.

Finally, as mentioned above, Modulus has created artificial blood with an increased oxygen carrying capacity through gene editing and modifying the structure of hemoglobin. More oxygen in the blood has many benefits and advantages. Not only does it provide humans with more energy, it enables the heart to work less hard and increases human lifespan [2].

2. Human-animal Hybrids at Modulus

Throughout past human evolution, hybridization occurred in many different instances, such as cross-breeding between Neanderthals and ancient versions of what are now modern humans. Some scientists have believed that particular genes of the Neanderthal may have been key to ancient humans' adapting to the harsh climates they faced when they left Africa.

The first stable human-animal chimeras (not hybrids but related) to actually exist were first created by Shanghai Second Medical University scientists in 2003, the result of having fused human cells with rabbit eggs [3]. Scientists announced in 2017 that they successfully created the first human-animal chimeric embryo. The embryo consisted of mostly pig cells and some human cells. Scientists stated that they hope to use this technology to address the shortage of donor organs [4]. In July 2019, Japanese scientist Hiromitsu Nakauchi got the approval of the Japanese government to experiment with inserting human stem cells into animal (particularly rodent) embryos [5]. Although its main use will be to make organ transplantation easier, this can be considered the first more effective step of making animal-human hybrids real.

At first, the goal of animal-human hybridization was to produce animals with organs made of human cells. These organs could then be harvested to be transplanted into people. Modulus wants to work to pioneer a medical revolution, paving the way for the modern day practice of in vitro organ production. Additionally, major advances in gene engineering and biomimicry could also make it possible for the human form to expand, and this can be used to better understand the ways in which we differ from other species, while in essence being biologically similar. Indeed, we are all made of different combinations of the same proteins and amino acids; our DNA is shared across species, but our experiences are what makes us different. At Modulus, we believe that the boundary between species is fluid.
Using biomimicry, what if we could create animal-human hybrids in order to enhance the human sensory experience? These augmentations could be used to better understand how different species differ from humans, and give us the ability to heighten our senses. For example, tigers have more rods (responsible for visual acuity for shapes) in their eyes than cones (responsible for color vision) to assist with their night vision. The increased number of rods allows them to detect movement of prey in darkness where color vision would not be useful. Tigers also have a structure at the back of the eye behind the retina called the tapetum lucidum that enables them to have better night vision. This mirror-like structure reflects light back into the eye a second time to help produce a brighter image. In general, cats require only about 1/6 the light humans do to see. At Modulus we want to be able to reproduce a tiger’s eye using biomimicry and cutting edge stem cell research, giving consenting people the ability to enhance their visual experience. Moreover, the tiger’s sense of hearing is the most acute of all its senses and is mainly used for hunting. Their ears are capable of rotating to detect the origins of various sounds, but most impressively they can hear within a much larger range of frequencies (0.2 kHz to 65 kHz, we have a hearing range of about 0.02 kHz and 20 kHz). What if we could reproduce tiger ears and implant them in human patients?

Moreover, at Modulus we believe in morphological freedom, and therefore the freedom to choose your uniqueness. It is a known fact that every tiger has a unique pattern of stripes on their fur and skin, mainly used for camouflage needs and temperature control. We want to allow people to change their appearance as a form of self expression and personal identity, which is why we also believe in allowing certain biomimetic aesthetic enhancements of the human form, such as having striped fur on parts of your body.

According to the Human Hybridization and Embryology Act of 2030, humans who have internal or genetical modifications for medical purposes, as well as humans who undergo biomimetic enhancements are considered to be fully human by the law and society.

3. Artificial bones at Modulus

As part of our research at Modulus, we delved into the science behind bone regeneration and the future of artificial bones. Bone regeneration is made possible by the interaction between two kinds of cells: osteoblast and osteoclast. The first one is known as a giant cell (with a diameter of about 50 μm), and it independently breaks down bone tissue. Osteoblast, on the other hand, is a small cell with a diameter of about 10 μm, and it synthesizes new bones by working with many other cells. Bones are always regenerating through a perpetual cycle of bone resorption and bone formation.
Problems usually arise when a bone is damaged or removed due to disease and/or injury. In that case, how can the body regenerate it? It is for this reason that scientists have been working to create artificial bones as a solution to this problem. In Japan, professor Junzo Tanaka from the Tokyo Institute of Technology has been working for over 20 years on developing new bone materials.

"Bones are much stronger than people think. A bone about the size of a sugar cube can sustain the weight of ten 150 kg sumo wrestlers. However, strength alone is not sufficient for artificial bones to fully integrate with our own bones." [6]

In the past, artificial bones have successfully been made using materials such as metals and solid ceramics. Unfortunately, their rigidity made it difficult for these new bones to blend into bone tissue. In the 1980s, artificial bones made of hydroxyapatite (hydroxylated calcium phosphate) were created, and were at the time the most similar to the natural bone structure. These materials could in fact be reabsorbed and replaced by natural tissue over time. But the problem of rigidity still existed [7].

One idea for the future of artificial bones is to get inspired by nature, and the regenerative capacity of fish scales. Using biomimicry to create artificial bones could solve the current issues scientists are facing. In an experiment jointly conducted with Hokkaido University School of Medicine, scientists observed that transplanting high-intensity artificial bone using fish scale collagen into rabbits regenerated their bones in three months compared to six months using pig collagen. In other words, the regeneration speed was twice as fast using fish scale collagen.

More recently in 2017, a University of British Columbia Okanagan researcher has discovered a new artificial bone design that can be customized and made with a 3D printer for stronger, safer and more effective bone replacements [8]. They believe artificial bone grafts could be custom printed to potentially fit any patient and wouldn't require transplanting existing bone fragments.

Modulus want to make sure to design artificial bones using highly effective biomaterials, with the key criteria being biocompatibility, osteoconductivity (the ability of bone-forming cells in the grafting area to move across a scaffold and slowly replace it with new bone over time), high porosity and biomechanics compatibility. Research on artificial bone materials has revealed that bioactive and resorbable silicate glasses (bioglass), glass-ceramics, and calcium phosphates exhibit mechanical properties to human bone [9].

Similar mechanical property does not assure biocompatibility. The body's biological response to those materials depends on many parameters including chemical composition, topography, porosity, and grain size. In reality, the current scientific advances on artificial bones pose many challenges and limitations. At Modulus, we want to bridge the gap between the customizability of 3D printing and the material and mechanical advantages of materials like bioglass. Using biomimicry to enhance the regenerative properties of newly developed materials could solve many of the current issues with biocompatibility.
4. Gene engineering and the future brain at Modulus

Historically, in the field of biotechnology, two of the biggest milestones were the discovery of the molecular structure of DNA and eventually the decoding and reading of the human blueprint. In 1953, American biologist James Watson and British physicist Francis Crick pioneered the field of gene engineering by discovering the famed double helix structure of DNA. Almost 50 years later, in 2003, two international teams of researchers led by American biologists Francis Collins and Craig Venter succeeded in decoding and reading that blueprint by identifying all of the chemical base pairs that make up human DNA.

Without these two discoveries, none of the current advancement in genetic science would have been possible. At Modulus, decoding the human genome is considered the foundation of all of our biotechnological research, and has given us the opportunity to alter human physiology at its most fundamental level. Genetic engineering is known as the process of manipulating this genetic code; and it allows us to enhance and elevate the human experience. Theoretically, gene engineering can be used to give people stronger muscles and faster brains, but it has the potential to create people with gills, webbed hands or even wings.

The development of gene engineering grew exponentially thanks to inexpensive and sophisticated gene mapping technologies, which allowed scientists to better understand the human genome. But one of the most important developments in gene editing technology was the discovery of CRISPR Cas9. CRISPR is a protein which plays a vital role in the immunological defense of certain bacteria against DNA viruses and plasmids, its main function is to cut DNA, and therefore it can be used to alter a cell's genome. Scientists have been able to use it as a tool to induce site-directed double-strand breaks in DNA. In 2015, Cas9 was used to modify the genome of human embryos for the first time [10]. On June 21, 2016, the U.S. government announced that it had approved the first human trials using CRISPR, in this case to strengthen the cancer-fighting properties of the immune systems of patients suffering from melanoma and other deadly cancers. CRISPR could provide new treatments or even cures to some of today’s most feared diseases – not only cancer, but Alzheimer’s disease, Parkinson’s disease and others [11].

In the future, Modulus wants to make available the possibility of having genetic changes at the embryonic stage, also known as germline editing. The goal is to alter the gene lines in an embryo’s eight or 16 cell stage, and that change will occur in each of the resulting person’s trillions of cells – not to mention in the cells of their descendants. When combined with
researchers’ growing understanding of the genetic links to various diseases, CRISPR could conceivably help eliminate a host of maladies in people before they are born. Our belief in morphological freedom is not our only concern, we actively want to fight to elevate humanity and eliminate hereditary diseases that could negatively impact people’s lives.

Moreover, brain augmentations and cognitive enhancements could dramatically change our ways of life. In that sense, Modulus believes that the straightest and shortest line to dramatically augmenting cognition probably involves computers and information technology, often referred to as BCI (Brain Computer Interface). Advances in computing and nanotechnology have resulted in the creation of computers that can interface with our brains. This development is not as far-fetched as it may sound, since both the brain and computers use electricity to operate and communicate.

Some early and primitive brain-machine interfaces have been used for therapeutic purposes, to help restore some mobility to those with paralysis (as in the example involving the quadriplegic man) and to give partial sight to people with certain kinds of blindness [12]. In the future, we believe scientists can develop brain-machine interfaces for many other applications, from helping stroke victims regain speech and mobility to successfully bringing people out of deep comas.

Right now, most scientists working in the brain-machine-interface field say they are solely focused on healing, rather than enhancing. However, at Modulus we believe that the technology developed to ameliorate medical conditions will inevitably be put to other uses, and this will involve augmenting brain function. As an example, scientists have been using electrodes placed on the head to run a mild electrical current through the brain, a procedure known as transcranial direct-current stimulation (tDCS). Research shows that tDCS, which is painless, may increase brain plasticity, making it easier for neurons to fire. This, in turn, improves cognition, making it easier for test subjects to learn and retain things, from new languages to mathematics [13]. Already there is talk of implanting a tDCS pacemaker-like device in the brain so recipients do not need to wear electrodes. A device inside someone’s head could also more accurately target the electrical current to those parts of the brain most responsive to tDCS.

We believe in taking this a step further, according to Raymond Kurzweil, by 2029, we will have completed the reverse engineering of the human brain [14]. This will allow scientists to model and simulate all the regions of the brain, providing us the algorithmic methods to simulate all of the human brain’s capabilities including our emotional intelligence. Once scientists complete a detailed map of exactly what different parts of our brain do, they will theoretically be able to augment each function zone by placing computers in these places. For example, machines may allow us to “process” information at exponentially faster speeds or to vividly remember everything or simply to see or hear better. This is part of the human transcendence at Modulus.
5. The Challenges and morality of Implementing Human Augmentation

Nowadays, the field of Synthetic Biology is seen as full of potential. However, the possibility of hypothetically creating artificial life has also created concerns about the nature of life and raises philosophical questions regarding the laws of nature, humanity and the process of creation [15]. As we set out to develop the idea of a company that exists in a future where it is possible to get augmentations or enhancements in order to live a longer and richer life, we started by researching the current debate that surrounds the technologies that might make it possible.

For our project, we analyzed the possible advantages and disadvantages this type of service could bring to humanity from different perspectives and what new challenges would present, and divided them in categories depending on its possible ramifications:

| Feasibility | From a scientific point of view, the technological advances in recent years have been impressive and even though the field of Synthetic Biology is still in its infant years compared to other fields, it’s not reason enough to doubt the infinite possibilities it has to offer even from a theoretical and speculative standpoint. We can also count on the considerable investments that countries like the USA, the United Kingdom, and China are doing with regards to research in the field of Synthetic Biology, for example funding several projects and agencies within their governments to promote the advances of this field. Modulus is a speculative project based in the current state of the scientific field and aims to question how present decisions and discoveries could affect the future of our society. |
| Human Identity | When discussing human enhancements or augmentations, one of the main topics of debate is whether these modifications “will alter human nature or ‘humanness’” [16] according to George Annas, and serves as one of the main reasons to stop or at least heavily regulate the development of technologies that could alter the human body. But as Elizabeth Fenton refutes in her paper, we cannot base our ethics under the assumption of an existing unidentifiable characteristic that is not based on an existing universal definition that maintains public legitimacy. |
Collaboration

Morphological Freedom as an inherent right to maintain or alter our bodies [17] is one of the core values we used when building Modulus vision, because as we studied human identity, how we present most of the times comes from a desire to reflect our inner aspirations and desires. As a social commentary we want to support morphological freedom that truly reflects your personal identity.

At Modulus, we spent a long time discussing the morality of genetic enhancements, and the potential difference and distinction between enhancements that are intrinsically beneficial to the general population, and enhancements that provide positional advantages. Often, the goal of augmentation is for something extrinsic to become intrinsic. However, we wanted to make sure to prioritize and value enhancements that have the most ubiquitous and universal value first, like improving general health and cognitive abilities.

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<td>One of the main concerns when it comes to technology is the possibility of the ‘dual uses’ people can come up with by accident or purposefully with the development of new technology [18], or even the creation of a bioterrorism weapon by biohackers [19]. While these scenarios are impossible to fully prevent, we can work towards regulation that will make them highly improbable. And in the event of a crisis, we need to know how to act and who would be responsible in those cases, which is why it is important that the debates are held beforehand, highlighting the importance of creating context through speculative design.</td>
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<td>Another important element when considering regulatory law is avoiding the creation of inequality and monopolies in the patents. Indeed, it is imperative to avoid adversity and hardship for certain regions due to new technology neutralising resources from a poor region, like what occurred with the creation of synthetic artemisinin [20].</td>
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<td>In Modulus’s case, we decided that a future where this type of service could exist is a future where technology can move forward without restrictions, but with different levels of regulation, starting from a self-regulated level and going all the way to an international agency that could oversee jurisdiction and permits, considering every party, the impact levels and the benefits.</td>
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<td>We strongly believe that international collaboration is the key for the progress of technology and science. We are living through a historic time in which we are fighting a global pandemic, demonstrating how international collaboration is essential if we intend to find a cure for any disease. But it is not only the scientific community that needs to come together.</td>
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<td>The scientific community needs to raise their concerns for social conversation before they occur at the hands of misinformation, while</td>
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maintaining public legitimacy and support. This can only happen if they come together and take the lead in debating these issues. By partnering not only with other scientists but with civil organizations and ethicists, we can begin to have conversations regarding emerging scientific fields which society might find controversial.

As a result, we aim to start a social conversation by proposing a future in which a company like Modulus exists as a result of an active collaboration between scientists, policy makers, civil groups, and ethicists by addressing questions with our project that could lead to developing ethically acceptable and public supported policy.

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<td>One of the main challenges scientists face when developing new technologies is explaining how the new technology works in an understandable way so that policy-makers, citizens and governments could get a clear idea of how the technology will affect our society in every aspect of our lives.</td>
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<td>The reality is that humans are narrative animals and we will fall back on narratives before picking up a science book [21]. This is something that we as scientists need to understand to better explain research or technology, because the possibility of any technology receiving support or funding from the governments rely heavily on the alignment of their objectives and common understanding.</td>
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<td>The storytelling for Modulus is one of the key parts of this project, by reflecting on which parts of our project we wanted to highlight as a result of long conversations about identity, bioethics, and our desired future. We want to focus on the optimism and promising parts of human enhancements, in an attempt to inspire law makers and scientists by showing them a future in which the possibilities are defined by each person and not by our skin color, social environment or gender.</td>
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References