Life in Liquid

A Weightless Biological Architecture

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Imagine a world...

in which gravity is absent,
humans breath liquid,
membrane is building material,

...and a new weightless
architecture is formed.

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Within the discourse of architecture there have been few attempts to expand past the confinement of earth's continental land mass and into other environments. While historically there exists proposals spanning from the marine cities of modernity to the underwater biospheres of present, designers have yet to plunge into the most challenging environment of all, liquid. One of the most notable materials to exist in liquid is the cell membrane, a substance that is inherently biological.

In order to create a liquid architecture, biological processes must be utilized. The ability for a biological process to develop in three dimensions only becomes possible with a weightless environment; liquid possesses the unique ability to simulate weightlessness on earth, facilitating a weightless architecture. In this case, liquid becomes a crucial factor in both the form and functionality of the system.

From humans' time in the womb, liquid aided buoyancy has allowed for the embryo to growth and self-structure in all dimensions. A return to this system enables an entirely new way of building; site becomes liquid, material becomes membrane, and humans breathe fluid as opposed to air.

Through the use of these systems, an inhabitable liquid membrane structure is feasible.

This thesis will examine the consequences and design possibilities that are propagated by the use of a liquid environment. The use of biological membrane processes in conjunction with an underwater site allow for an architecture distinguishable from traditional land design. With gravity and the consequences it brings absent from the environment, form takes on the potential of a new method of design.

What is life?

A truly biological architecture is something that has been examined for decades yet never fully achieved. Biological systems present some of the most challenging problems, delicate structures, and intricate interactions of any other system on Earth. Is it possible for us as humans to create a biological system that in turn becomes our habitat? Can our built environment be 'living' and grow, develop, and decay just as we do?

As with any organism, humans possess the ability to alter the environment in which they inhabit, and with this comes both positive and negative ramifications. We would not be living if we were not changing the world in which we grow and evolve. However, with this evolution and growth we have both advanced our society beyond imagination and caused more destruction than ever thought possible.

Some of these changes have saved lives, made humans healthier, allowed our population to explode to unprecedented levels. More of these changes have destroyed our environment, caused mutations in disease that we can no longer keep pace with, and ironically, created an overpopulated planet. Land is now at a premium, and we have exhausted the resources available.

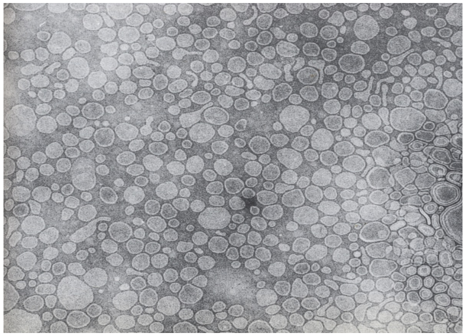


Figure_1.1

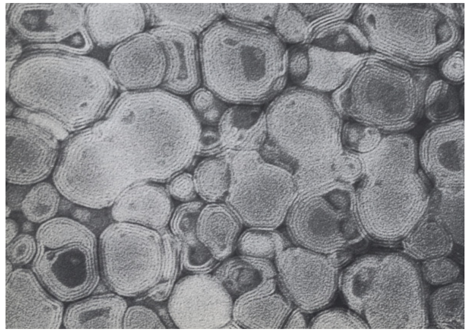


Figure_1.2

In order to change the way in which we build and live, we will have to change our society. Presently, building is done in order to contain and protect; contain the objects that reside within it and protect from the environment outside its walls. In order to properly interact with the biological environment that surrounds us, we need to explore the possibility of a permeable enclosure. Why does a building have to keep nature out?

Humanity has spent so much time trying to control the interiors of these spaces that we have in fact created an entirely new environment, one with no regard to the way in which actual atmospheres operate. This brings the very definition of space comes into question, whether a separate inside and outside need to exist in actuality or whether two environments can come to reside in equilibrium without barriers or confinement.

Imitating and re-creating biological systems has been in practice throughout architectural history. Attempts are frequently made to design architecture that stems from nature, though it is not possible to simply create nature. Transmitting natural merely replicates the systems in place. However a truly 'natural' system regenerates and regrows, evolves and consumes.

Living systems are genetically based, each growth or replication is inherently linked. By following these parameters, perhaps it is possible to fill information with flesh and make it inert. However, it is always

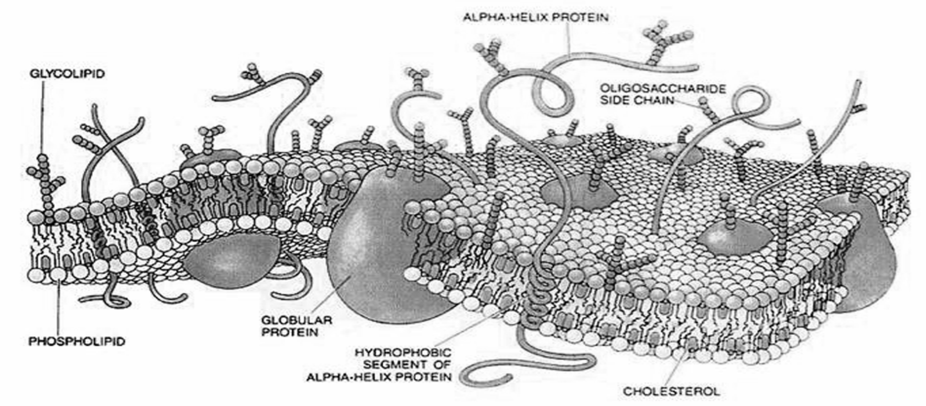


Figure_1.3

questionable whether something natural can ever be re-created, as wouldn't this make the re-creation no longer natural? To answer this question we have to define what is natural.
Natural systems are living systems, and the definition of life has precise parameters that must be met, so then what is life?

In the biological use of the term, 'living' has a very concrete definition. For an object to be living it must posses the following characteristics: feeding, movement, respiration, excretion, growth, sensitivity and reproduction. In a broader sense of the word, this definition can expand to include objects not only biologically deemed 'living' but objects that also adapt and evolve with the environment in which they exist. Organisms not only live in the environment they occupy, they change and shape the environment. Creating a living architecture suggests a fusion of both biologically living materials and the architectural definition of space.

Cell membranes have always shared an inherent discourse with the buildings that we create. The sole purpose of a cell membrane is to protect the inside contents of the cell from the outside environment. Is this not what we are replicating when we design buildings, the main goal being to protect one environment from another? In this context it becomes clear that we are in fact building in the same logic as cell biology. Could we not then gather inspiration and information from this organic phenomena? Organelles in a cell are essentially the same functionally as rooms in our buildings. The need to compartmentalize spans both biological and mechanical systems.

The environment in which this new living architecture manifests itself becomes of vital importance given the restraints enacted by biological process. One of the most important characteristics of the cell is that it exists in liquid. This fact cannot be ignored.

Every environment possesses its own innate qualities that shape the life that forms within its constraints. In the context of building, gravity stands out as one of the most dynamic qualities to consider. The gravitational conditions on earth, under the water, and in space vary drastically. If we are to successfully build in any of these environments, the characteristics of gravity and pressure must be taken into consideration. These restraints will no doubt deeply affect the way in which we build, and the types of built environments

we create. Without these restraints, design becomes unstable and obsolete.
Stability can both refer to the physical soundness of a structure and the social ramifications of a fixed and unchanging style of architecture. In this sense, it would be easier to create a socially unstable way of design than an unsteady building. In order to imagine unstable structures, we have to stop referring to architecture only in the sense of physical buildings. Architecture does not have to be a rigid, unchanging, and unmoving form. Perhaps it is possible for our built environments to move with us and change and evolve as we do, therefore creating the ultimate "unstableness."

It can be hypothesized that some of the formal and aesthetic criteria that has been important throughout architectural history will become obsolete as we move towards more biological systems. Biological systems develop functionally rather than aesthetically. However, we must keep in mind that some of these criteria have been in place as long as they have because they pose both useful and practical to both the designer and the user. We have to remember we are not only designing for architects, but society, and society has become accustomed to a certain aesthetic. In order to successfully integrate biological architecture into our built environments, we must be sensitive to these issues, otherwise they will most likely fail. Society must be ready for a living, changing system in order for it to thrive; the ultimate flexibility.

Though the typical building may not appear as a living organism, it in fact shares correlations to the biological definition. While not scientifically accurate, buildings create waste (most of the time too much) as well as feed off of resources. A house requires resources, some for the occupants inside, some to keep the house in a livable condition. With this in mind we can questions whether a house is living, or only appears to be due to the living organisms that occupy it. Perhaps in the future it will be possible to have our house both protect us from our environment as well as growth, evolve, and decay in accordance to our lifespan.

A New Biological Architecture

The most common and in a way, most logical form of biological matter to translate into architecture is the cell membrane. As stated previously, the functionality of the two are inherently linked. If the function matches, form can follow.

The use of membrane as form has been explored in the architectural realm for many decades. However, no attempts have been made to bridge the gap between true biological membranes and architectural form. One of the most challenging aspects of this link is the necessity of a liquid habitat.

In Farooq Hussain's book "Living Underwater" the history of human's quest to inhabit liquid environments is explored.[1] It is important to note that his text was published in 1970 during which modernity and Archigram were ending their presence. A great deal of design work was done concerning the marine city. Hussain begins by exploring human's first underwater exploration using the aqualung, and how that preceded further more complex research initiatives underwater. Hussain also notes the important difference between the lung of a human and the gill of a fish, and how oxygen intake is used in a similar fashion, however there are marked differences between oxygen found in water and oxygen in air.

Underwater vessels have been used throughout the past century to research and gain knowledge of the aquatic world. Recently, these vessels have even been used for tourism, demonstrating a popular

1 Hussain, Farooq. Living Underwater. [New York]: Praeger, 1970. Print.

curiosity regarding the sea. However, each of these vessels have been entirely scientifically based. Each underwater habitat is mechanically designed for optimal research performance and not much else.

This raises the question of underwater design. With the synthesis of biological and mechanical properties, dynamic design can truly take place. Liquid interaction becomes as important as form and function. New technologies allow humans to exist underwater without the aid of mechanical devices. Liquid breathing can be utilized to facilitate human existence underwater. Without the hassle of frequent pressure changes and air supply, a new ability to explore is available. Humans can therefore exist in liquid, almost effortlessly.

Liquid facilitates not only the ability to explore, but the means for a new architecture, one of weightlessness. Weightlessness exists on earth, however it is never used. With the ability to develop and design in three dimensions, much like the computer allows one to draw without the constraints of gravity, a new form is possible. The mechanically designed 'blobs' that have been crafted are no longer structural feats, but rather biologically processed forms. From births to biology, biological systems allow for an underwater,

Figure_1.4

weightless architecture.

Comparing Air to Water

The differences between air and water are not purely physical. There is a great deal less oxygen per unit volume in water than there is in air. This means that a land based, air breathing animal would be able to survive twenty-five times longer on a liter

Figure_1.5

of air than compared to an equal volume of water.[2] Also, the density and viscosity of water is greater than air. We have all experienced how much more difficult it is to move through water than through air. Naturally, an air breathing human would need to exert a great deal more energy in order to move an equal distance in water as compared to land.

2 Ibid.

These important differences would necessitate a complete overhaul of our current notions of traditional survival tactics. With a completely new medium surrounding our society, a new form of living would be necessary.

How Organisms Use Air and Water

The differences between the way air and water are used in organisms has to do with "the speed that oxygen and carbon dioxide are exchanged through the semi-permeable membranes in the lung of an air-breathing creature and in the gills of a fish."[3] One of the biggest differences between the gill and the lung is "related to the transfer of oxygen and carbon dioxide between the respiratory organism and the gas exchange medium."[4]

Using this logic, it is possible to conceive of the idea of humans being able to mimic the function of a gill and possibly use this to breath or perhaps live underwater. One begins to question whether or not it would be feasible for humans to maintain a lifestyle that takes place entirely in an aquatic environment. Just as the fetus is designed to move from the liquid environment of the womb to the air filled environment we are accustomed to, it is entirely possible that the human species may one day evolve back to a liquid environment.

3 Ibid.
4 Ibid.

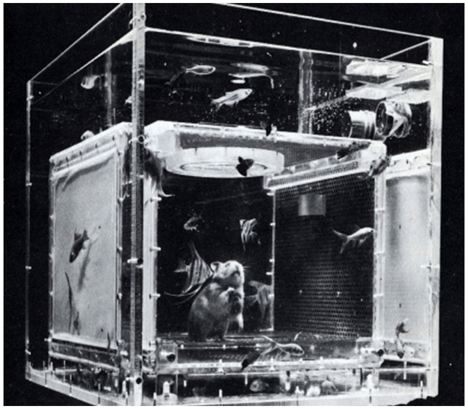


Figure_1.6

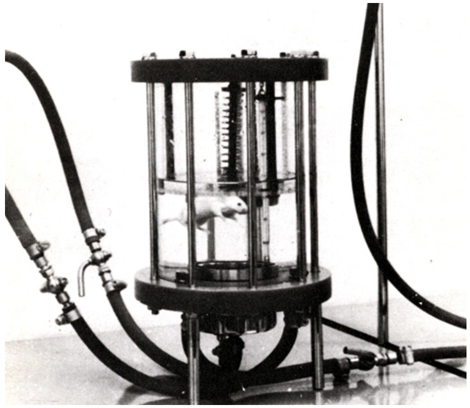


Figure_1.7

Breathing Underwater

With the aid of current technological advances, it has become possible for air breathing animals to breath liquid. (see figures_1.6-7) Humans can utilize a liquid called Liquivent that can contain twenty five times more oxygen than blood. This method is currently in use by the U.S. Navy. The liquid used in this technique generally has a perfluorocarbon type composition. Since Liquivent is more dense than regular water, it allows for twenty five times more oxygen than blood and can be used to help patients with lung and breathing disorders. Using this method, fluid is taken into the lungs. This makes it possible for the pressure in the body to match the surrounding water.

One of the advantages of liquid breathing is that there is no need for decompression, which can lead to afflictions like nitrogen narcosis and the bends. This technique has been tested widely on rats, and humans have in fact survived liquid breathing. The key to liquid breathing is the fluorocarbon liquid that does not cause toxic build-up in the lungs.

The concept of breathing liquid gained

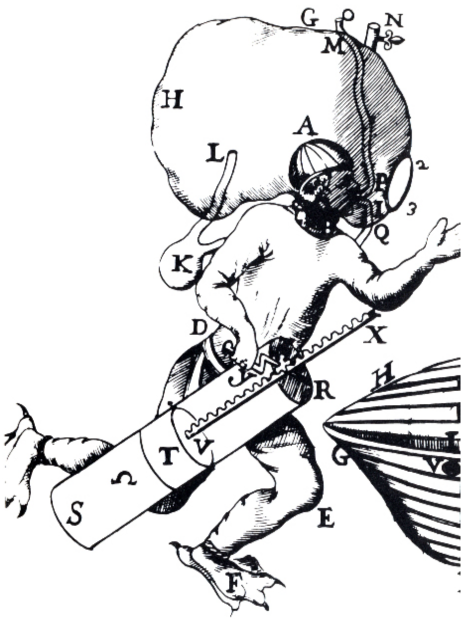


Figure_1.8

popularity from the 1989 James Cameron film *The Abyss*. In the film, a rat is submerged in a liquid chamber and eventually takes the liquid into its lungs and begins to breath. Later in the film, a human diver uses the same technique in order to dive to previously impossible depths.

In this science fiction film, the concept of liquid breathing is explored as a means of diving to otherwise impossible depths. The first instance of this is seen when a scientist uses a rat to demonstrate the possibility of an otherwise air-breathing animal to breath liquid. The rat is completely submerged and at first appears distraught due to the change. As the rat's anxiety from being forced underwater grows, it slowly begins to adjust to its new environment. Slowly, the rat begins to take the liquid into its lungs. As this transition takes place, the rat becomes more and more calm with the change. Once the rat has calmed down and adjusted to the change in pressure, the rat begins to breath the liquid as it would normally breath air.

Later in the film, a creature formed completely of water appears to the characters. This creature has an underwater world created deep in the ocean. This holds cultural significance in that during this decade, liquid computational modeling was first being explored. This fascination carried over into the film.

It is decided that a human will dive using the liquid breathing technique originally tested on the rat. A man is placed in a dive suit with a spherical glass helmet covering his head. This helmet is filled with liquid that he at first resists and then slowly takes into his lungs and breaths with ease. Using this technique, he is able to dive to levels otherwise impossible. This technique does not exist only in science fiction, as it has come to be proven by science.

The World's Water

We inhabit a planet that encompasses in liquid. The majority of surface on Earth is covered in water, making it even more relevance to speculate on a future move to liquid environments.

On this Earth 86.5% of the bodies of water are oceans. Although oceans are commonly thought of a separate from one another, they are all one in the same. It is important to note that "the oceans and the atmosphere are intrinsically linked, the atmosphere drives the circulation of the oceans and influences the composition of seawater."[5]

Because of this relationship, the atmosphere "in turn owes its nature to and derives its energy from the ocean... The ocean and atmosphere are the two unique fluid forms which cover the earth."[6] Therefore, when one examines the atmosphere, one must also consider the ramifications any changes made will also affect the oceans, and vice versa. Can

5 Ibid.
6 Ibid.

a change to one not be destructive to the other? We must be rigourous in our pursuit of either entity, for the earth's unique systems are intrinsically linked. If we were to one day create a society underwater, in the ocean per say, how would this in turn affect the atmosphere, and further, the state of dry land?
Oceans, however, do not provide the only means to facilitate an underwater world. While oceans provide the largest natural body of water, freshwater lakes, streams, ponds, and rivers also suggest possibility. Man-made liquid tanks provide a stage for liquid design and experimentation as well. The environment in which a liquid architecture takes place is not limited to natural.

Modernity's Aquatic Exploration

During the height of modernity, Archigram drew much inspiration from maritime activities, examining research vessels such as SEALAB along with others in order advance the architectural discipline. Examples of this fascination with underwater environments includes Kikutake's Marine City, Buckminster Fuller's Underwater Island (1963) and Warren Chalk's Underwater City Project (1964). The technological advances necessary to build in an underwater environment resonated

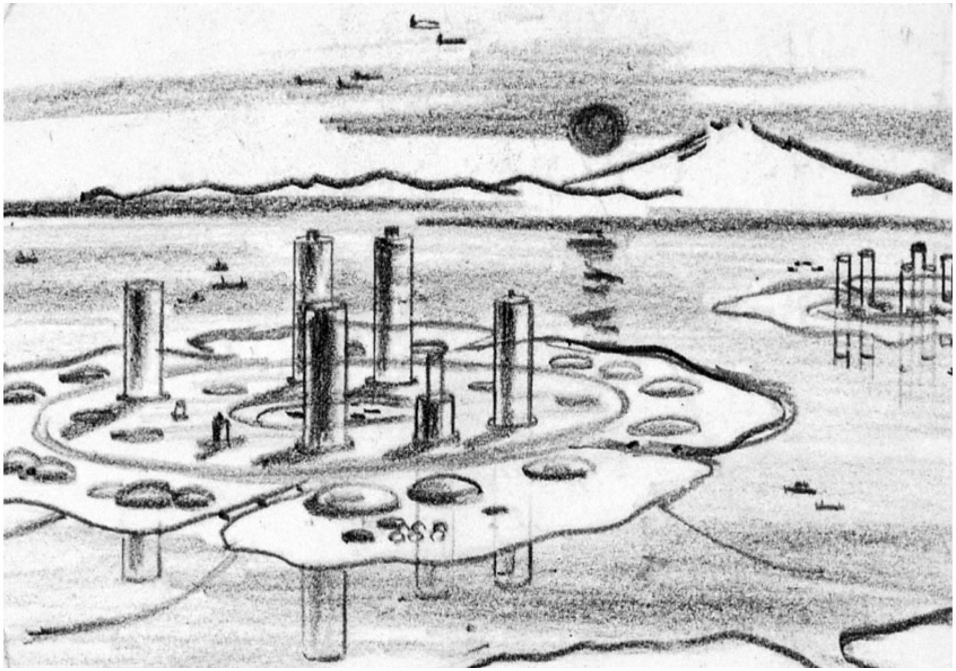


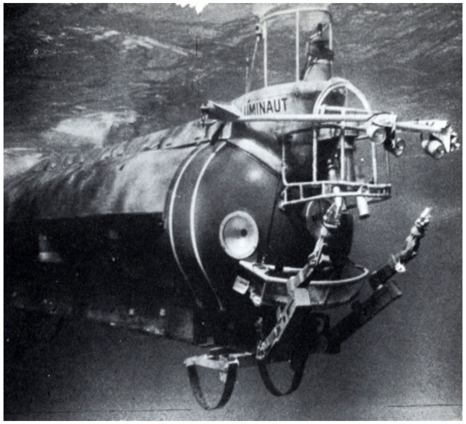
Figure_1.9

with Archigram's need to design for the future and push the discipline farther. Water provided an unknown environment along with unpursued opportunities and challenges. With Archigram's push for futuristic technologies and machines along with an abundance of experimentation, the ocean provided a much needed new frontier, untapped by other designers.

In 1962. Cousteau's Precontinent experiments were executed. This helped to fuel an interest in underwater architecture. These experiments included aquanauts, also examined by Farooq Hussain in his text "Living Underwater." The concept of humans being sustained underwater for long periods of time was not a new concept, but one of the first times to be executed successfully. The exploration of the sea as a possible human environment was paralleled by the Metabolist Movement in Japan during the same time period.

The Metabolist Movement began in Japan in the late 1950's. It consisted of a group of young architects and designers. These designers' focus consisted of exploring possible solutions to urban problems in an innovative way, mainly through industrial rather than architectural means. Unlike Archigram, the Metabolist group did not rely on architectural principals. In 1961, member Kiyonori Kikuatke presented his project "Marine City" at the "Visionary Architecture" exhibition at the Museum of Modern Art in New York. (see figure_1.9)

The move to water represented a new approach to urban design, consisting of more flexible structures and societies than those presently residing on land. Mass production was emphasized, similar to in the text "Climbing Mount Improbable" where a super computer's sole purpose is replication efficiency, like in most biological systems. Kikutake spent a great deal of time researching ocean engineering and construction techniques to make



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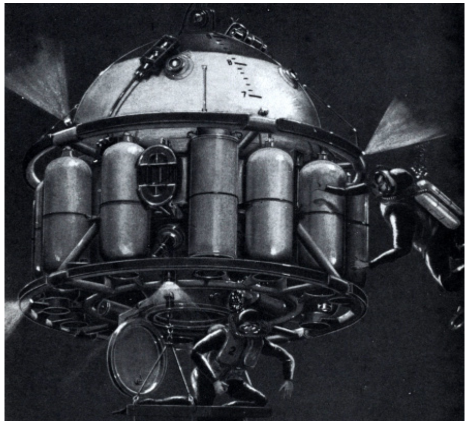

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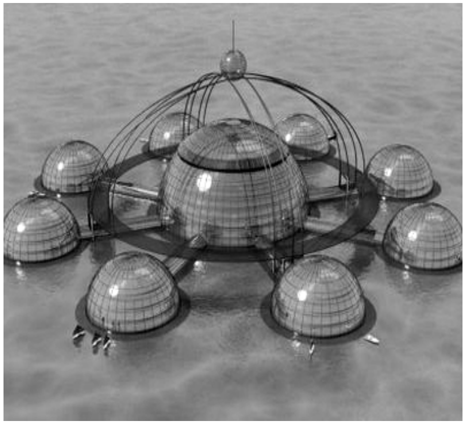

Figure_1.12

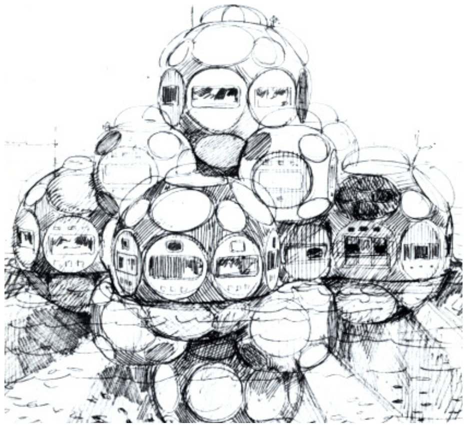

Figure_1.13

the possibility of water design a feasible solution to current problems, mainly a lack of physical space to build. However, this proposal was critiqued for its lack of concern for preserving natural systems and the environment. Most notable of this project is that it is floating rather than submerged, dissimilar to Farooq Hussain's request for true underwater inhabitation.

Underwater Environments

The concept of an underwater habitat for humans to survive in was conceived by the U.S. Navy in the form of an experiment called SEALAB. (see figures_1.10-11) The first of these experiments was SEALAB I which was deployed off the coast of Bermuda in 1964 and traveled to 58 meters below the sea surface. In 1965, SEALAB II was launched off of the coast of California and was submerged 62 meters below the sea surface. SEALAB II was refurbished into SEALAB III in 1969 and lowered off the coast of California to 185 meters below the sea surface.

The officials that boarded these underwater vessels were referred to as "aquanauts". An aquanaut is defined as "an individual who stays underwater exposed to the ambient pressure long enough to come into equilibrium with his or her breathing."[7]

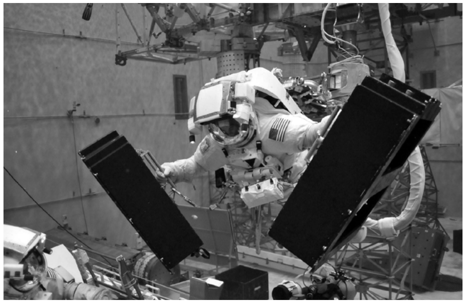

Figure_1.14

Other underwater environments have been conceived since SEALAB. The NOAA Aquatic Reef Base is the world's only underwater research facility and The Scott Carpenter Space Analog Station is NASA's sea floor research station.

U.K. based designer Phil Pauly conceived of a biosphere that floats atop the ocean and can submerge fully. He called this "Sub Biosphere 2: A Self-Sustaining Underwater City." (see figure_1.12) This underwater habitat would be completely self-sustaining for use by aquanauts, tourists, and oceanographic life sciences.

The entire city would be capable of being submerged. It would "maintain and support life while acting as a secure underwater seed bank."[8] The design would be able to

Figure_1.15

fully support itself, including air, water, food, electricity and other needs.

Another water inspired design was that for the Lilypad: Floating City for Climate Change Refugees. This concept strives to conceptualize a solution to the world's one day housing shortage. Designed by Vicent Callebaut, the city would be self-sustaining and float above the water but not submerge.

From these design embarkments, infinite questions arise. Can we use nature as a way to build. Looking into cell membrane organization, can the hierarchy that is so intrinsic to its structure translate to a scale in which humans can inhabit? Are these biological materials practical and useful in creating a new type of built environment? As examined before, it is perhaps necessary for us to change society as well as the world

7 Ibid.

8 http://www.inhabitat.com/2010/06/16/sub-biosphere-2-a-self-sustaining-underwater-city/

around us.

Neutral Buoyancy | Weightlessness

With the use of a liquid environment so vital to a biological architecture, it is necessary to begin to examine the possibilities presented by using such a system. One of the most spectacular assets that liquid presents to us is that it provides the only opportunity on Earth for weightlessness.

Neutral buoyancy describes the phenomena in which an object has an equal tendency to float and sink, making the objects appear as if it is weightless, or hovering. To make something neutrally buoyant, a combination of weights and flotation devices are used. This is similar to objects in orbit.

However, it is important to note that the object, if living, can still feel and sense his or her weight, unlike in low gravity situations. Also, unlike in orbit, the creature still experiences the drag of the surrounding water or liquid, making it more difficult to move.

Due to neutral buoyancy's similarity to reduced gravity conditions, it is utilized for EVA, or Extravehicular Activity, training among astronauts. (see figures_1.14-15) The sensation of being weightless is used to allow astronauts to prepare for trips into space. Like stated previously, there are some limitations to this method, including water drag and the ability to sense one's true weight.

With liquid providing such a spectacular possibility for weightless design, it is paramount that this characteristic is utilizes in future underwater design. Liquid design in a weightless environment possesses the ability to both revolutionize and revitalize present day architecture and building practices.

Towards an Underwater Weightless World

Using the knowledge gained from biological processes and aquatic design possibilities, it is imperative to create a design that utilities the strengths each of these systems present. With environment as liquid and material as biological matter, a new type of design is eminent.

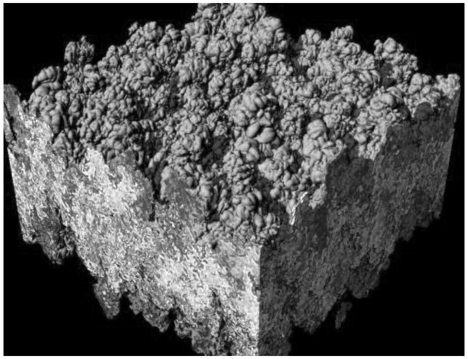

Figure_2.1

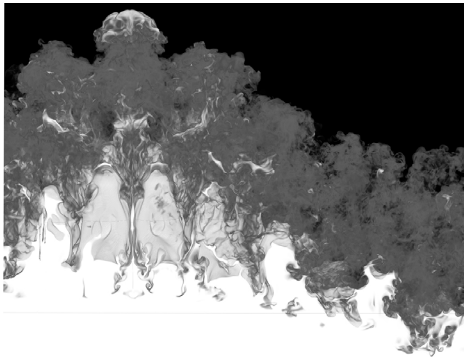

Figure_2.2

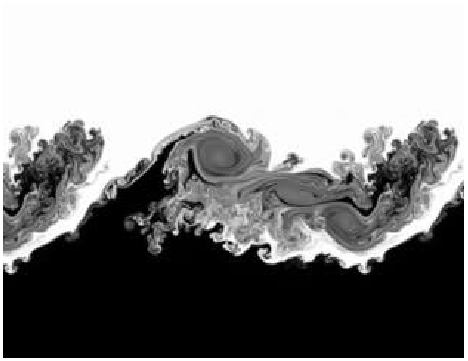

Figure_2.3

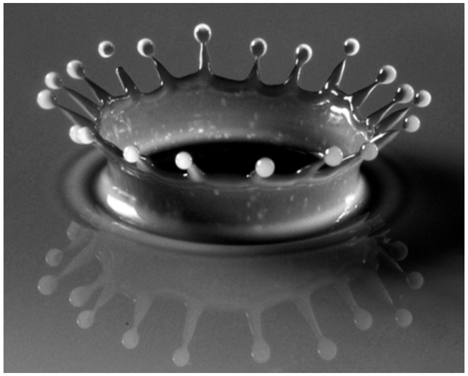

Figure_2.4

The Science Behind Liquid Instability

Liquids perform in an entirely different way from the rigid materials so common in design today. In order to fully grasp the magnitude of unstable material practice, experimentation is necessary.

One of the most prudent aspects of liquid material is that it is unpredictable and unstable. No experiment is going to perform in the same way more than once. With this uncertainty in final form and function, flexibility needs to be incorporated into the system. The so called accidents that result from these endeavors become discoveries in material practice.

There are four main types of liquid instability. Rayleigh-Taylor instability (see figure_2.1) is the instability that occurs between two fluids that are of varying densities. This phenomena is seen when two fluids are attempting to reach equilibrium. In this case, the less dense fluid causes movement of the heavier fluid.[1]

Kelvin-Helmholtz instability (see figure_2.2) is the instability that occurs when velocity shear is imposed within a continuous fluid. This effect is seen as waves along a liquid surface.[2]

Richtmyer-Meshkov instability (see figure_2.3) is the instability that occurs when the film that is present between two fluids of different densities is excited by acceleration. When this happens, bubbles occur if a light fluid is interacting with a heavy fluid, and spikes occur if a heavy fluid is interacting with a light fluid.3

Plateau-Rayliegh instability (see figure_2.4) is the instability that occurs when a liquid is somehow altered into droplets. It explains why a falling steam of liquid disperses into smaller droplets that are the same volume but less surface area than the original. [4]

Understanding the dynamic motion between fluids and the basic principles of fluid interaction is critical to liquid design. Both pressure and lack of gravity play an important role in how materials form. In order to maintain a grasp of the nature of such materials, a series of experimentations were carried out. These studies demonstrate the most basic forms of liquid interactions and then move into more complex and formal model making.

Liquid as Environment

The use of biological membranes severally limits the context in which a design can be maintained. The most important restraint regarding membrane design is the need for a liquid environment. Without this crucial factor, all other considerations are moot. Practically, a site would have to consist entirely of liquid. Water becomes the new frontier for design. Contextually, liquid provides the means for both membrane existence as well as weightlessness.

There are numerous possibilities that facilitate a liquid environment on Earth. The most consuming being the ocean, followed by fresh water bodies and artificial basins. A system such as this could thrive in any of these environments given that certain conditions are maintained. The biological membrane will exist in liquid as long as it remains protected by a thin layer of oil or wax. However, in order for plant life to thrive, sunlight and chemical balance must be considered. This eliminates the deep trenches of the world's ocean. Seawater, however, does maintain a more buoyant environment than fresh water, mainly due to its salinity.

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1 Calder, Alan. "Rayleigh-Taylor Instability." http://www.astro.sunysb.edu/acalder/val.html (21 September 2010).

2 Cabot, William H., Andrew W. Cook, Kyle J. Caspersen, James N. Glosli, and Liam D. Krauss. "Kelvin-Helmholtz Instability." APS Physics. http://www.aps.org/units/dfd/pressroom/gallery/richards.cfm (21 September 2010

3 Woodward, Paul. "High Performance Computing." The Laboratory for Computational Science & Engin. http://www.lcse.umn.edu/index.php?c=about (21 September 2010).

4 van Hoeve, Wim, Tim Segers, Detlef Lohse, and Michel Versluis. "A Splash of Red." eFluids Media Galleries. http://media.efluids.com/galleries/aip?medium=626 (21 September 2010).

When physical restraints are considered, two different bodies of water are left: seawater and freshwater. Both of these bodies encompass different restraints and opportunities. Perhaps it is possible that the system can thrive in both environments and adapt to the conditions present.

In addtion, scientific settings, such as a liquid research tank, provide a possible platform for such a system to exist.

For the purpose of experimentation,
all types of settings will be
utilized in the following studies.

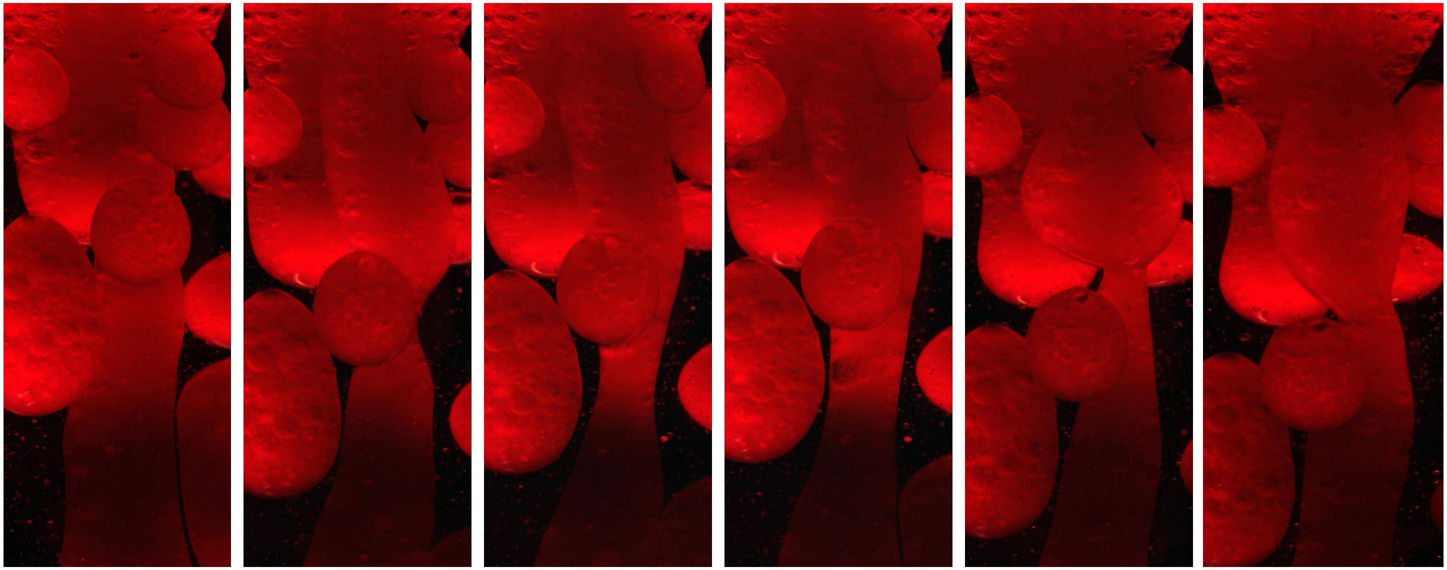


Figure_2.5

Study_01: Lava Lamp

Lava lamps function as a result of wax being heated in a liquid and then rising and falling within a glass enclosure depending on the heat level. The base of the lamp contains an incandescent bulb that provides the heat for the interaction to occur. On top of the base sits a glass chamber filled with clear liquid with glycerol derived additive. This provides the environment for the wax to interact in. (see figure_2.5)

At room temperature, the wax rests on the bottom of the glass chamber. As the base increasingly heats the liquid and wax, the wax becomes less dense than the liquid and begins to rise. When the wax reaches the top of the chamber, which is at room temperature, the wax slowly descends back to the base. This movement creates the illusion that the wax is weightless for a short period of time.

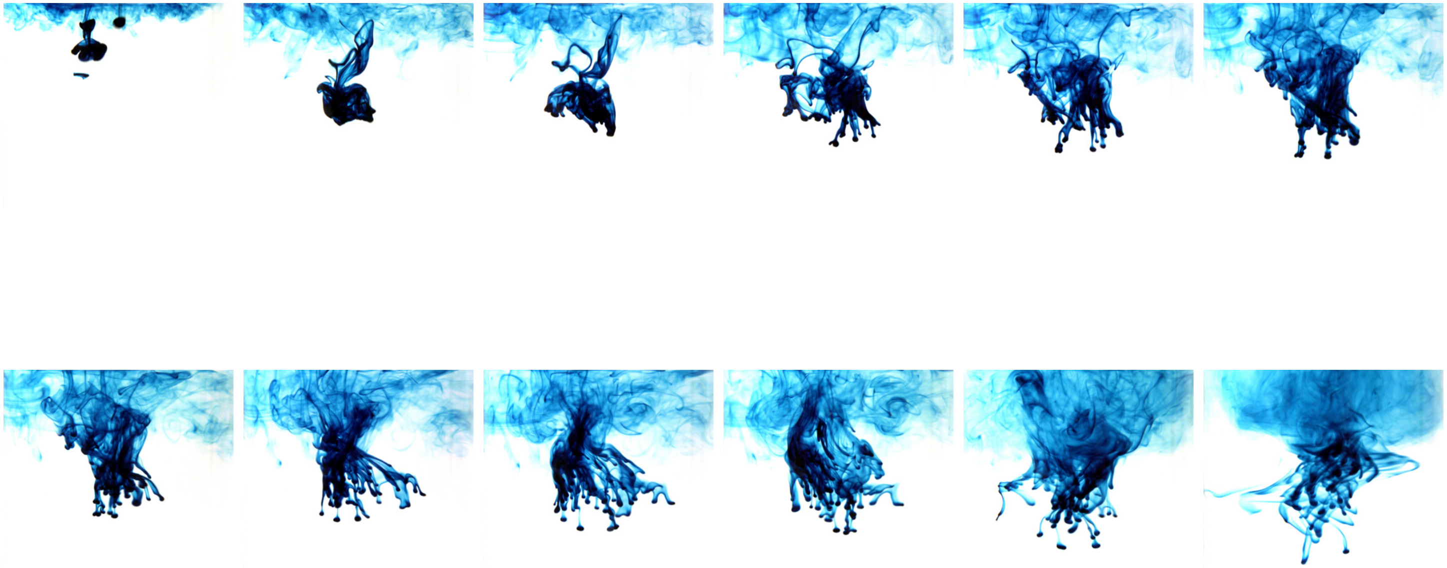


Figure_2.6

Study_02: Dye in Water

This experiments examines Rayleigh-Taylor Instability, which occurs between two fluids that are of varying densities. This phenomena is seen when two fluids are attempting to reach equilibrium. In this case, the less dense fluid moves the heavier fluid. Standard food dye is slightly more dense than regular tap water. Due to this, the dye penetrates the water. As seen in figure_2.6, as the dye is carefully dropped into the water, it quickly explodes into a cloud of finger-like forms.

The dye continues to pass through the water until it has reached the bottom of the chamber. The dye then slowly engulfs the water, however, it does not mix together unless stirred. When this phenomena is viewed in plan as opposed to section the dye takes on a spiral pattern as it interacts with the water.

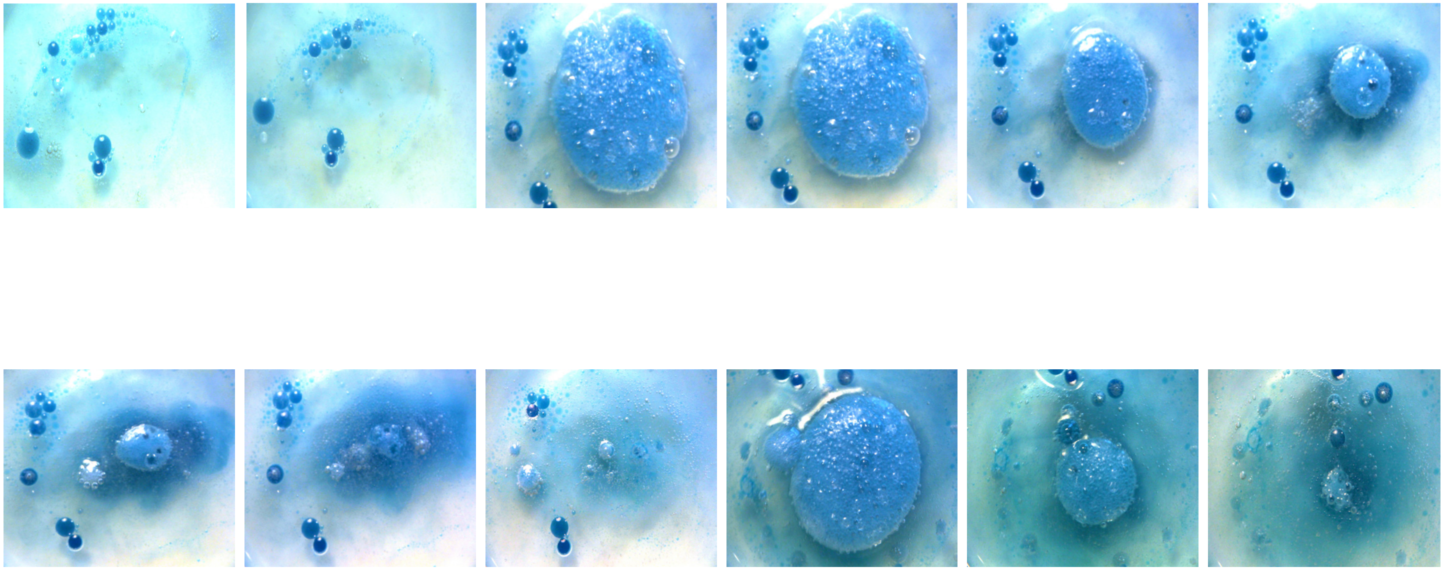


Figure_2.7

Study_03: Material Interactions

This experiments examines the effects of different liquids, varying both compositionally and in density. These various liquids were observed interacting with one another in a controlled environment.

In figure_2.7, layers were used to explore interactions. First, a layer of baking soda, then a layer of oil, then an injection of vinegar where imposed sequentially into the system. As seen in figure_2.7, an explosion of sorts follows the injection of vinegar. There is a mushroom cloud of foam bubbles that emerges to the top of the liquid layers growing in size at first, and then slowly reducing. The mushroom cloud then returns for a second explosion, before dissipating for good.

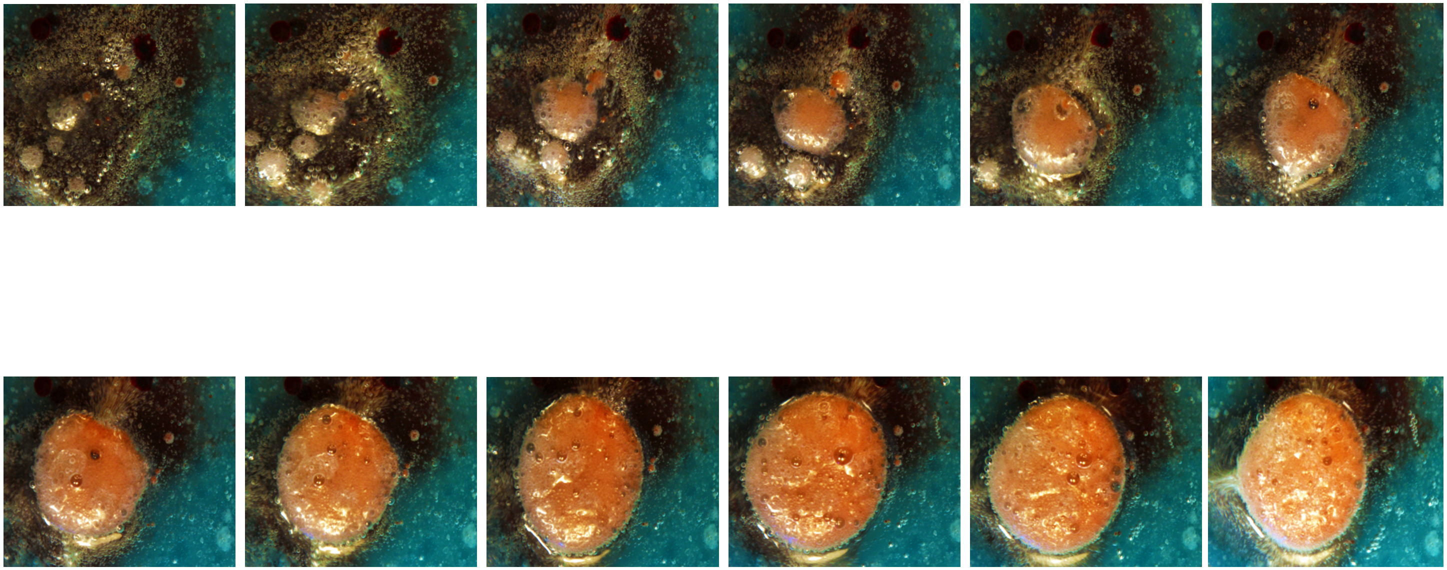


Figure_2.8

In figure_2.8 and figure_2.9, a set-up similar to the previous experiment is used except gelatin is added to the system along with two different colors to differentiate the layers. The additional color help to further contrast the bubble explosion from the liquid that fills the vessel.

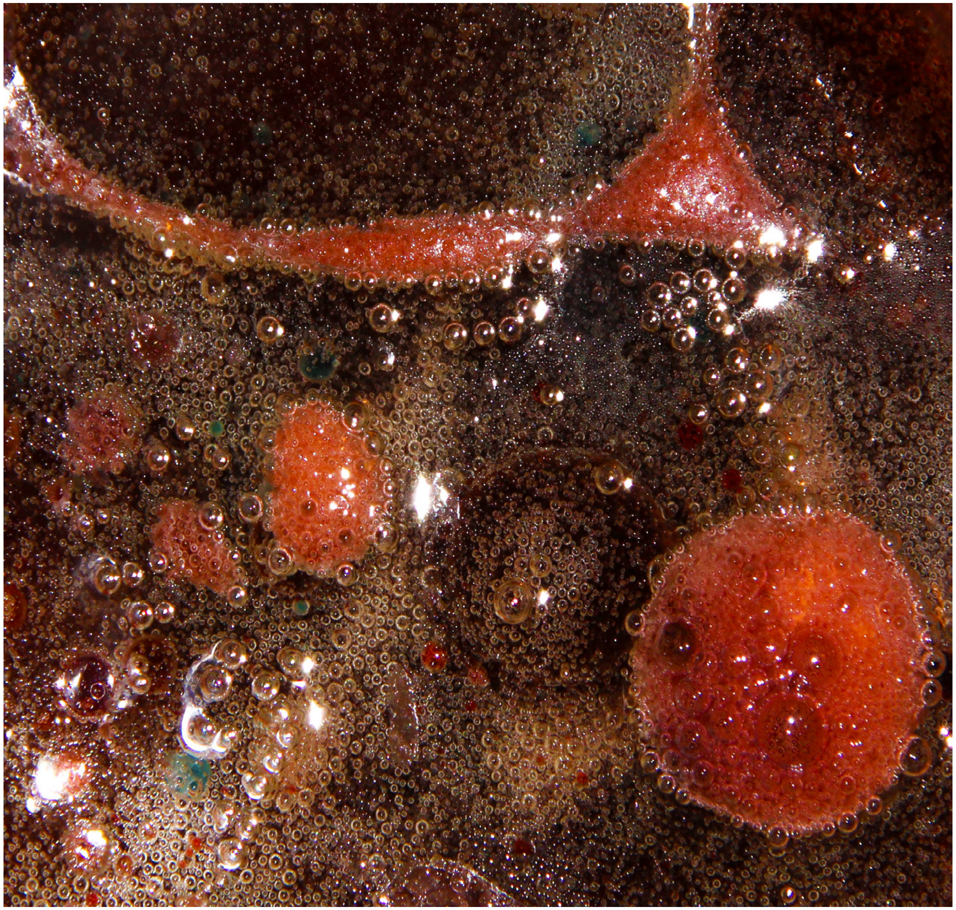


Figure_2.9

Figure_2.10

Study_05: Jelly Membranes

gel-a-tin:

1: glutinous material obtained from animal tissues by boiling; especially : a colloidal protein used as a food, in photography, and in medicine
2a : any of various substances (as agar) resembling gelatin b : an edible jelly made with gelatin

This series of experiments was completed using gelatin. Gelatin is a biological polymer and is considered a biological material. When heated, gelatin melts into a liquid, and when cool it becomes a solid.

For all but one of the trials, gelatin and water were combined at a ratio of one part gelatin to two parts water. For the remaining trial, a ratio of one to one was used, which resulted in a firmer, more dense material. The jelly mixture was used to create three dimensional bubbles using latex balloons. It was also used as a sheet that was then shaped and cooled. The mixture was colored in order to enhance the visual affects and one of the trials was scented and flavored. As the gelatin shapes cool, the water evaporates from the gelatin mixture, therefore distorting the shape.

It is important to note that the ratio of gelatin to water and the rigidity of the membrane are inherently linked. The more gelatin that is used in relation to water, the more rigid the resulting material is. This is due to a smaller concentration of water being present in the material, therefore allowing less evaporation and increasingly less distortion to occur.

In addition, the thickness of the membrane plays an important role in the final form. The thicker the membrane, the less the evaporation of water affects the shape. The material is also stronger and withstands higher pressure.

While the hardened gelatin is more rigid, and in some ways stronger than the flexible form, the bendability of the warm jelly membrane allows for a great deal of movement while still maintaining the integrity of the system. This becomes important when the jelly membrane is submerged into an unstable environment.

A full analysis of gelatin deformation as well as a catalogue of studies conducted follows. For addition images, see Appendix 1.

Diameter	Membrane Characteristics				
60 mm	Gelatin by Volume	25 mL	50 mL	100 mL	150 mL
	Percentage of Volume	22.12%	44.25%	NA	NA
	Membrane Thickness	6.64	13.28	NA	NA
100 mm	Gelatin by Volume	25 mL	50 mL	100 mL	150 mL
	Percentage of Volume	4.77%	9.54%	19.08%	28.63%
	Membrane Thickness	2.39	4.77	9.54	14.32
0.305 m	Gelatin by Volume	2.97 L	1.49 L	.7428 L	NA
	Percentage of Volume	20.00%	10.00%	5.00%	NA
	Gelatin Required (33%)	0.98 kg	0.4917	0.25 kg	NA
	Water Required (67%)	1.99 L	0.99 L	0.49 kg	NA
	Membrane Thickness	30 mm	15 mm	8 mm	NA
0.610 m	Gelatin by Volume	23.70 L	11.85 L	5.92 L	2.97 L
	Percentage of Volume	20.00%	10.00%	5.00%	2.50 %
	Gelatin Required (33%)	7.82 kg	3.91 kg	1.96kg	0.98 kg
	Water Required (67%)	15.88 L	7.94 L	3.97kg	1.99 kg
	Membrane Thickness	61 mm	31 mm	15 mm	8 mm
1.22 m	Gelatin by Volume	190.15	95.08 L	47.54 L	23.77 L
	Percentage of Volume	20.00%	10.00%	5.00%	2.50%
	Gelatin Required (33%)	62.75	31.38	15.69	7.85 kg
	Water Required (67%)	127.40	63.7 L	31.85 L	15.93 L
	Membrane Thickness	122	61mm	31 mm	15 mm

Study_05.1: Membrane Deformation

Due to the nature of the gelatin material, a certain amount of deformation occurs throughout the drying process that affects the final form of the membrane.

In order to catalog the deformation that occurs during this process, a series of membrane were deployed. Varying amounts of material were poured into equally sized form work to allow for the analysis of shape.

As seen in the photographs, the thinnest membrane collapses in on itself while the thickest membrane largely retains the shape of the casting form work.

The table to the right indicated the exact procedures followed in order to conduct this study. A precise series of calculations was conducted in order to ensure the accuracy and hypothesis of the membranes.

Small Scale
(Rigid Framework)

100 mm - 25 mL

100 mm - 50 mL

100 mm - 100 mL

100 mm - 100 mL

100 mm - 150 mL

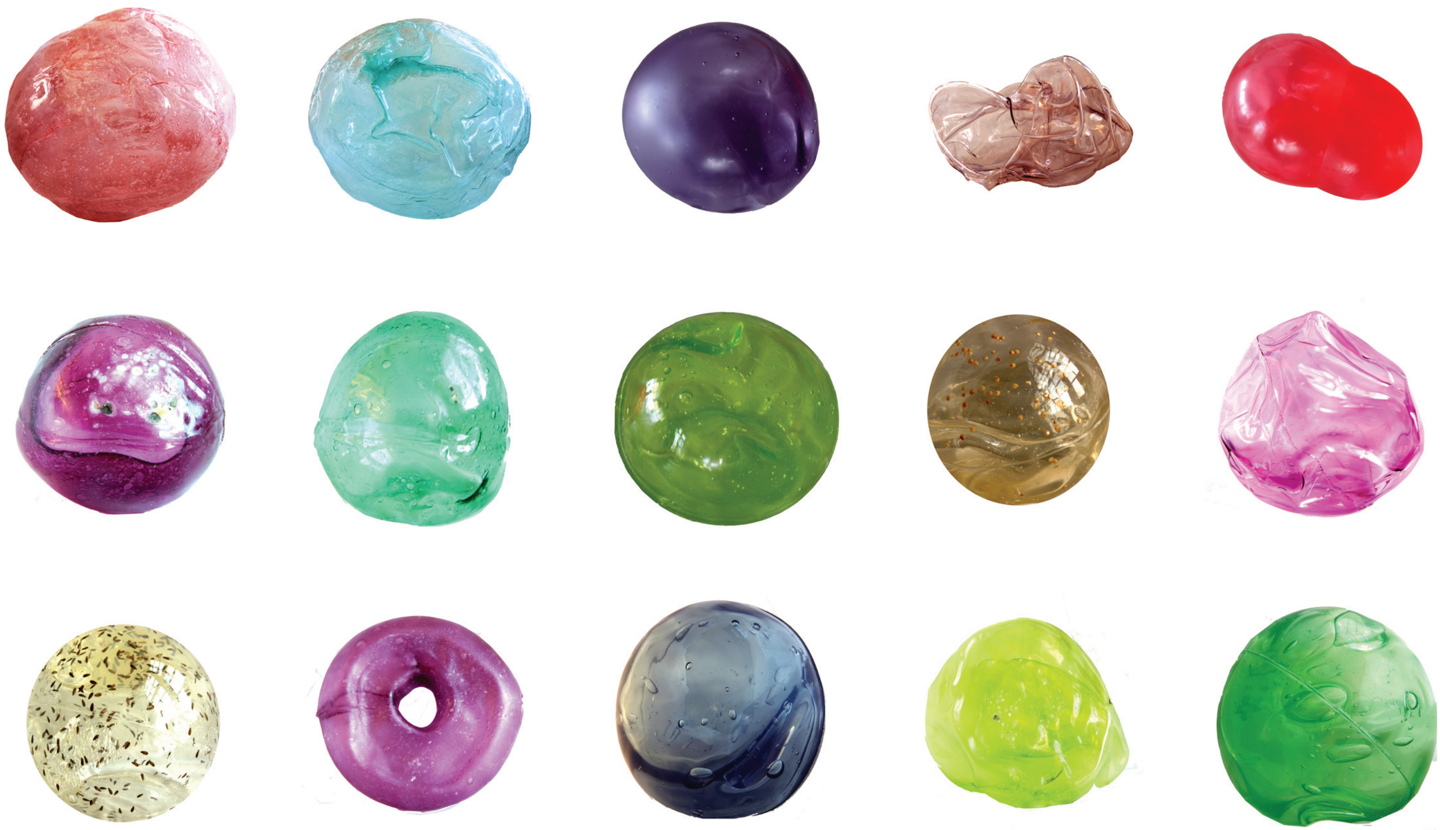
Large Scale
(Flexible Framework)

0.305 m - 1.46 L

0.305 m - 2.97 L

0.610 m - 2.97 L

Figure_2.11



Opposte: Figure_2.12

Opposite: Figure_2.13

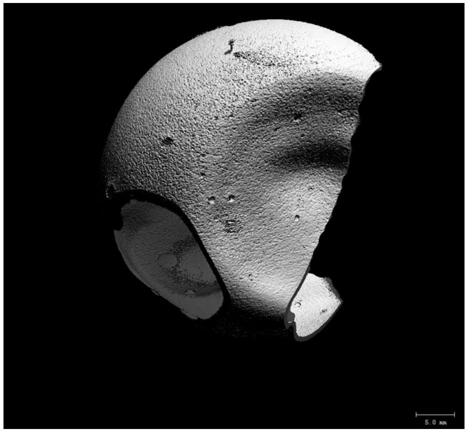


Figure_2.14

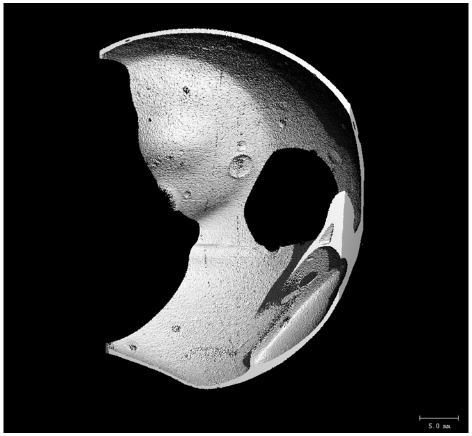


Figure_2.15

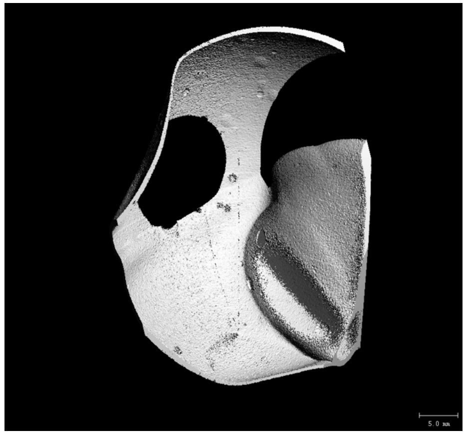


Figure_2.16

Study_06: CT Scan of Gelatin

As stated previously, gelatin is essentially animal bone that is combined with water and then formed. In order to explore this medium through a three dimensional forum, a CT scan was used. A CT scan is a three dimensional x-ray. For this study, a small gelatin sphere was placed into the machine and approximately 3,000 layers were read and then compiled into a digital model (see figures_2.14-2.16).

Gelatin as a Tool for Exploration

The full embodiment of the materials at hand require rigorous investigation of the design properties and possibilities that are inherent to the system. The principle means of material investigation, gelatin, allows for a multitude of experimental possibilities.

Through a series of design investigations, the use of gelatin as material, and liquid as habitat facilitate exploration of the system at hand. Further, the additional of plant life to the system hints at the possibility of a biosphere-like design; an environment where one can both inhabit and produce all necessary means of life.

Initial investigations navigate the phenomena of neutral buoyancy as well as both the challenges and advancements produced. Is a weightless architecture achievable? And more importantly, can this system be replicated in a way relevant to both society, designers, and researchers?

Further explorations divulge the implementation of biological processes into the gelatin matter. If plant life deems possible within such an environment, then a new form of forest emerges.

Pushing forward with this combination of systems, both living and inherently biological, comes a system which both grows in three dimensions as well as facilitate the liquid filled weightless environment of the original goal.

Mechanical alterations of this system prove to be both foreign and unsuccessful. Biological process prevails.

With the synthesis of all systems in a biological manner, a new architecture materializes.

Human's Move to an Underwater World

With the use of jelly materials and the technology of liquid breathing, a future move to liquid environments is possible for humans. As seen in nature, the fetus develops completely in liquid. This liquid environment allows the fetus to develop in several directions at once, gravity is not a limiting force. Taking neutral buoyancy into account, a weightless environment is possible on earth. Just as a fetus uses the weightlessness of liquid in order to form in three dimensions, human environments can exist underwater.

By using a jelly bubble underwater, divers would be capable of entering and exiting the bubble without a traditional entrance. The jelly skin would be able to self-repair itself. The use of a liquid breathing agent inside the jelly bubble would make breathing a possibility. Liquid breathing agents contain a much higher concentration of oxygen than water, making them less dense. This would aid in the weightless concept of the underwater bubble. In theory, the jelly bubble would exist without weight. Absent of weight, the jelly bubble would be free of restraints found in traditional design, mainly gravity.

The following investigations seek to explore the feasibility of this underwater world. The theoretical work of this thesis is completely mute if the material and physical investigation proves unsuccessful.

Neutral Buoyancy and Gelatin

For this study, a jelly sphere was extracted from its form work before the water contained in the membrane evaporated. The jelly sphere was injected with a 1:1 ratio of water to oil. This combination was hoped to allow the sphere to suspend in neutral buoyancy in a liquid environment. The jelly sphere was then placed into a liquid environment consisting of regular fresh water. The combination of water and oil contained within the sphere was hypothesized to mitigate the density of the jelly membrane with the exterior water condition.

As the sphere was placed into the liquid environment, it was immediately visible that a higher ratio of oil to water was required in order to achieve the desired affect. Oil was removed from the system and water was added. A small hole was pierced to allow for the escape of air from the sphere. Equilibrium was eventually reached through a trial and error process. The jelly sphere remained in neutral buoyancy for a moment's time before eventually rises to the water's surface and then slowly proceeding to sink to the bottom of the vessel.

The slow sinkage of the system was speculated to be caused by the membrane absorbing water into the system and therefore increasing the density of the sphere relative to the environment.

The movement of the jelly sphere throughout the experiment displays an important characteristic concerning gelatin and neutral buoyancy. It is important to note that the state of weightlessness achieved in the middle of the cycle is not a fixed state, but involves constant fluctuation.

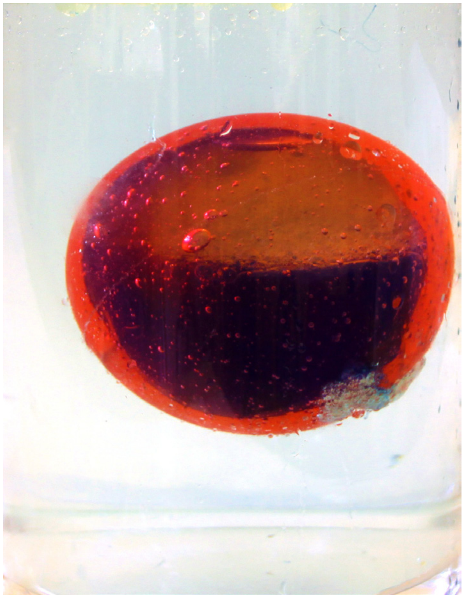
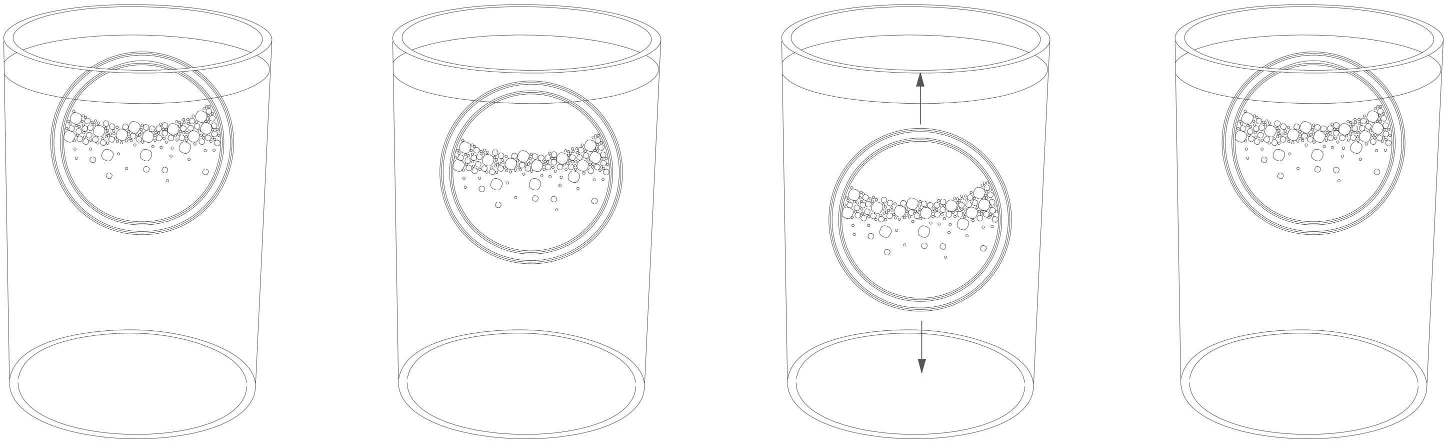


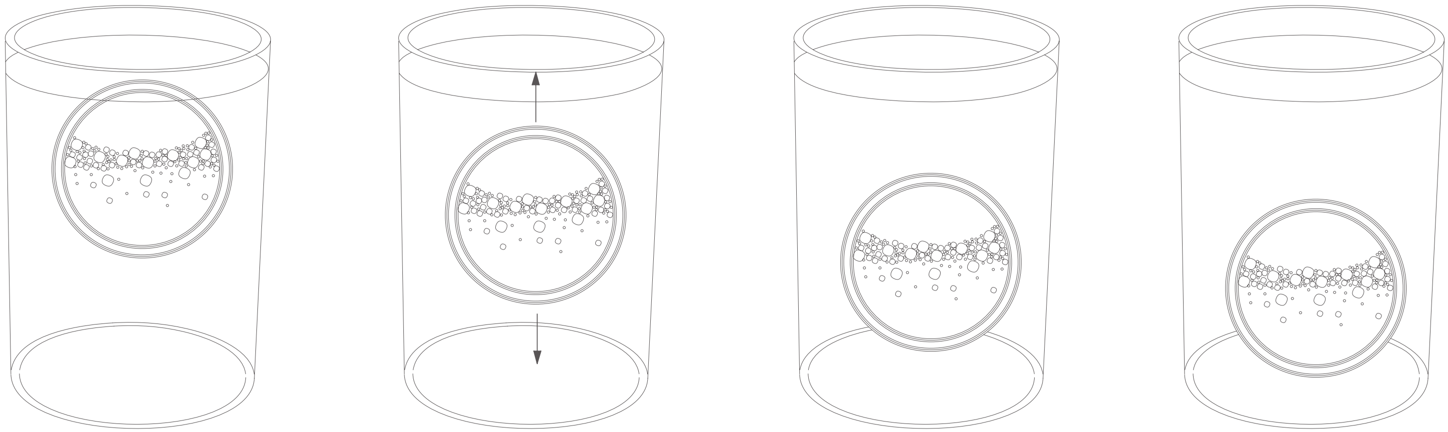
Figure_3.1

Figure_3.2



Neutral Buoyancy Achieved

Time: 0:00 | Time: 0:30 | Time: 0:45 | Time: 1:00



Neutral Buoyancy Achieved

Time: 24:00

Time: 48:00

Time: 60:00

Time: 72:00

Salt Water's Affect on Buoyancy

The salinity of seawater is approximately 3.5% with an average density of 1.025g/ml. As the density of seawater varies throughout the world, this can be used as approximations for the average amount of salt found in seawater. In order for life to thrive within the water, the salinity has to be careful controlled. Salinity has an important affect on density. In terms of buoyancy, varying salinity can either aid or detract from the ability of an object to float or sink.

With regards to the context of an underwater inhabitable system, seawater emerges as a likely contender. Given that the world's water mass vastly outweighs land mass, it is conceivable that an underwater biological system would exist in such conditions.

A hydrometer can be used to measure the salinity of a liquid. A hydrometer determines the specific gravity of the substance by being submerged and then observed.

For this study, the concept of neutral buoyancy was studied in terms of salt water. First, water was mixed with sea salt mix in order to achieve a salinity similar to that of seawater. The presence of salt in the water, which was not present in the previous study, made the water more buoyant, therefore making an object more likely to float than sink. A jelly bubble was injected with an underwater aquatic plant and water until 90% full. The jelly bubble was then submerged into the salt water mixture. Trial and error was used until the jelly bubble achieved neutral buoyancy. Over time, like in previous experiments, it is hypothesized that as time progresses, the jelly bubble will continue to absorb and retain fluid from its surroundings until it eventually sinks to the bottom of the vessel.

Figure_3.3

Figure_3.4

Multiple Membrane Buoyancy

In order to further investigate neutral buoyancy, a larger jelly sphere was constructed with smaller jelly spheres placed inside. A notable difference from the previous experiments was that the membranes were allowed to dry completely before this experiment was executed.

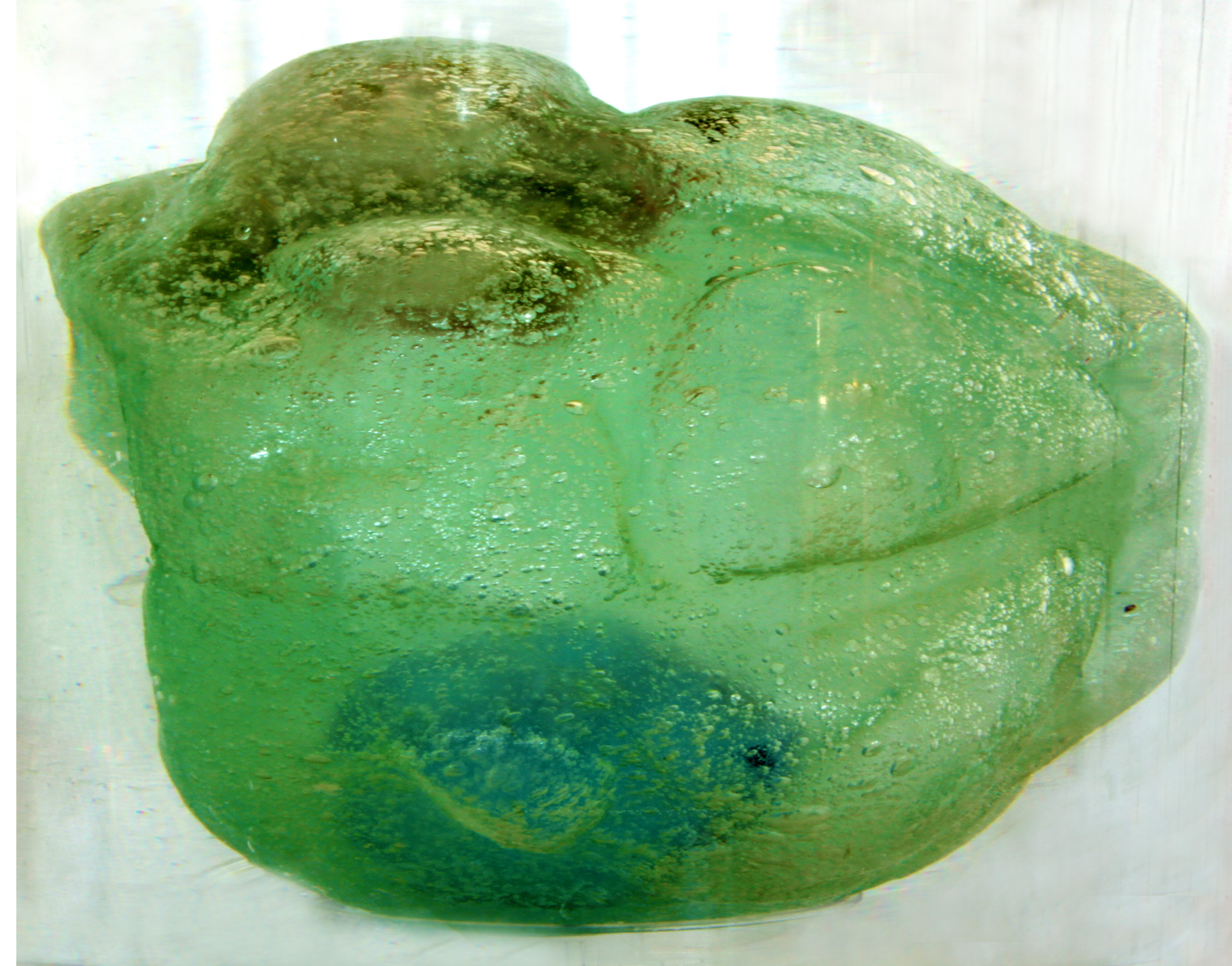
The allowance of the membranes to become rigid increased the lifespan of the system. Rather than decaying quite quickly, the membranes were slower to soften. The gelatin did, however, absorb quite a deal of water from the liquid filled tank, quickly returning it to its original jelly-like consistency.

The softening of the membrane created a very interesting movement within the liquid. When the membrane was displaced in any way, the entire system would become instable and liquid-like itself. This instability eludes back to the liquid characteristics noted in preliminary research investigations.

Large Outer Membrane: 0.305 m - 1.46 L

Smaller Inner Membranes: 100 mm - 100 mL

Opposite: Figure_3.5



Plant Life in Gelatin

In order for a system to be truly biological, it would need to not only be composed of biological materials but also provide a sustainable living environment. With this in mind, consider the possibility for gelatin membranes to grow and produce plant life for use by humans. Plants need the following conditions met in order for them to grow[1]:

1. Room to grow
2. Temperature
3. Light
4. Water
5. Air
6. Nutrients
7. Time

If the water used to create jelly membranes is not allowed to evaporate, then the need for water if fulfilled. The membrane also need be thick enough to allow enough room for the roots of the plant to grow. Jelly membranes can be made clear so light is not an issue. Time is also readily available. Three key factors are missing however, temperature control, air, and nutrients.

The only air available for plant life is the air trapped inside the membrane in the form of bubbles and the air contained inside of the sphere. Nutrients can be added to the gelatin mixture during processing. Temperature remains the largest issue. The temperature fluctuations experienced by the seeds during processing may provide unpredictable results.

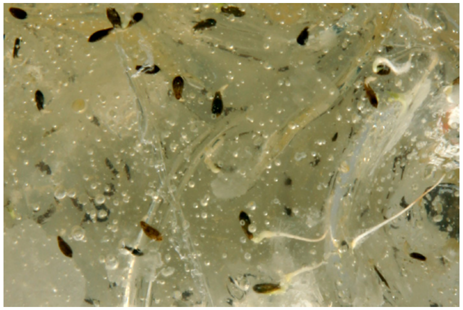
As indicated in the series of photographs the seeds did in fact grow in the gelatin membrane. The emergence of the seeds was quicker than expected, with results visible within days of planting. One of the unique attributes of growing seeds in a clear substance is the ability to view the grow through each stage. Rather than having to wait with traditional soil methods, roots are entirely visible to the naked eye.

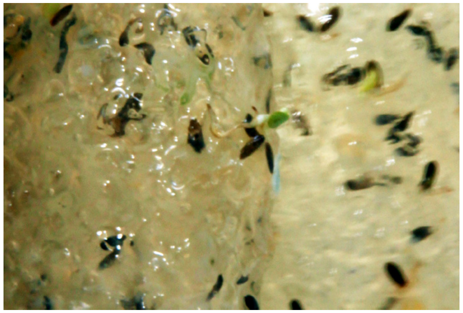
After a set amount of time, the membranes began to decay due to the high level of moisture, and therefore humidity, present within the small biosphere. This condition must be mediated for plant life to thrive.

1 University of Illinois Extension. "In Search of Green Life." http://www.calvin.edu/library/knightcite/index.php

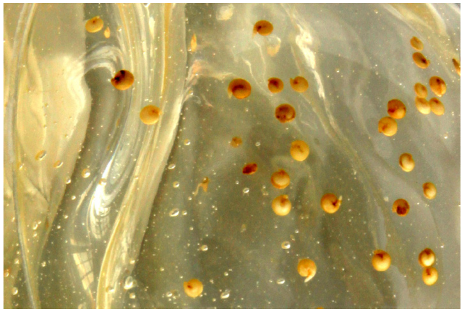
Lettuce Leaf ~ 500mg Planted: 10-28-10

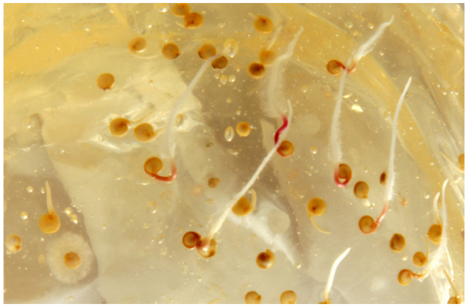

10-29-10: Day 1


10-30-10: Day 3


11-02-10: Day 5

Quinoa ~ 250mg Planted: 10-28-10


10-29-10: Day 1


10-30-10: Day 3


11-02-10: Day 5

Agar Membrane Experimentation

Through experimentation at the Center for Biotechnology, an agar membrane was created using a similar method to the one executed for gelatin membranes. Agar. 4% concentration, was poured into a plastic balloon framework along with various seeds and rotated to coat the globe. The seeds embedded in the agar will hypothetically grow into a three dimensional garden, as the membrane will be rotated every day so growth in any given direction is not shown a bias. The lifespan of this membrane will be significantly longer than if a duplicate membrane were made out of gelatin. The stability of agar as opposed to gelatin will greatly help the growth of the plant life within the system.

Figure_3.6

Figure_3.7

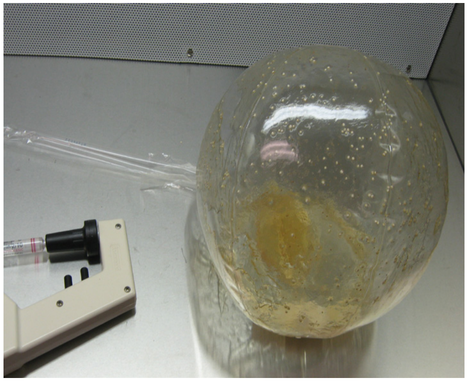


Figure_3.8

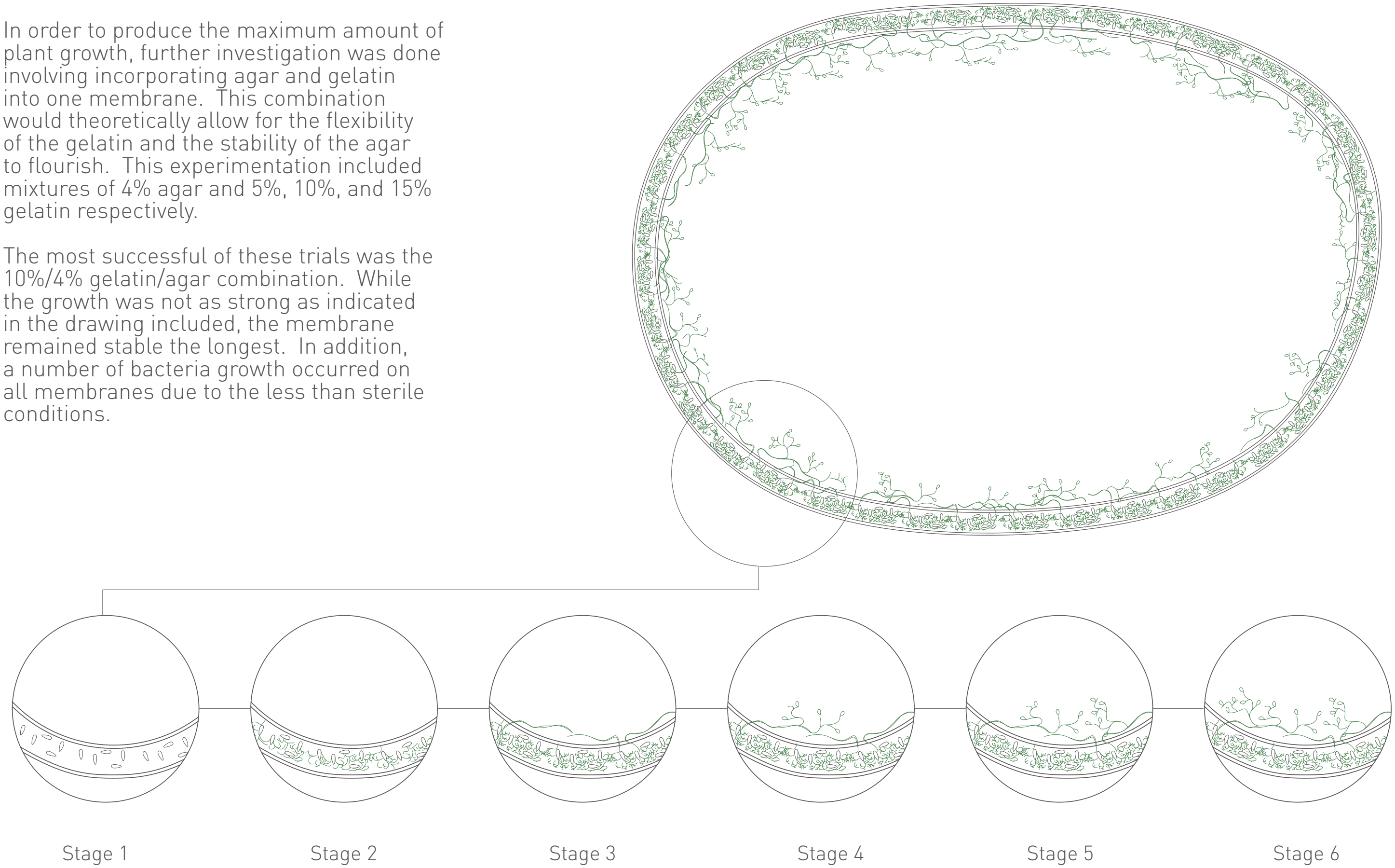
Figure_3.9

Figure_3.10

Hypothetical Growth

In order to produce the maximum amount of plant growth, further investigation was done involving incorporating agar and gelatin into one membrane. This combination would theoretically allow for the flexibility of the gelatin and the stability of the agar to flourish. This experimentation included mixtures of 4% agar and 5%, 10%, and 15% gelatin respectively.

The most successful of these trials was the 10%/4% gelatin/agar combination. While the growth was not as strong as indicated in the drawing included, the membrane remained stable the longest. In addition, a number of bacteria growth occurred on all membranes due to the less than sterile conditions.



Full Scale Membrane Installation

In order to fully encapsulate the behavior and capability of a membrane architecture, a large scale installation was required. Deploying a membrane at a human scale presents a number of challenges not previously encountered in smaller scale experimentation.

The preparation and process of such a membrane involves a number of stages, each critical to the success of the membrane. Initially, a framework is required. For this installation a large, clear vinyl balloon 48" in diameter was used to cast the membrane.

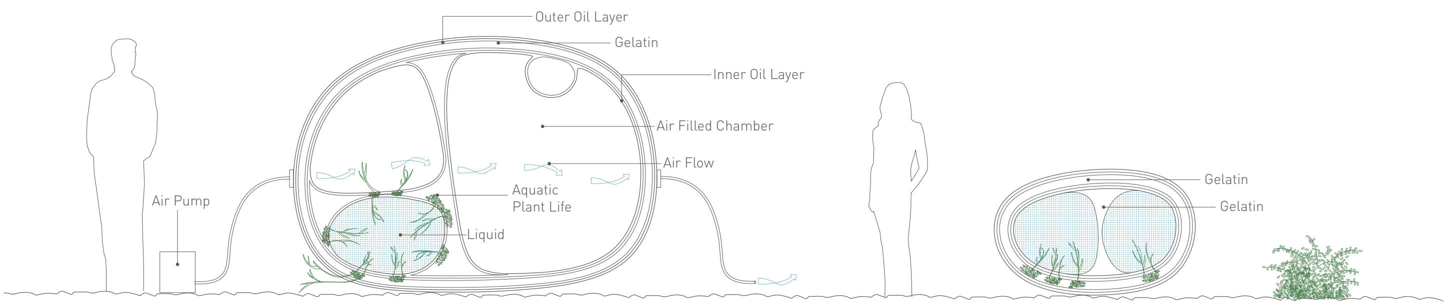
The material required for the membrane consisted of 8 kilograms of gelatin and approximately 16 liters of water. This mixture was combined by quickly mixing hot water into the gelatin powder. Quinoa seeds were also added to the mixture in speculation that they would germinate before the membrane dried.

This mixture was then poured into the balloon, after which all holes were closed and the membrane was rotated in a small swimming pool filled with water until the gelatin mixture coated the entire surface and cooled to the point of little motion. The membrane was then allowed to set and cool for approximately an hour before it was disturbed.

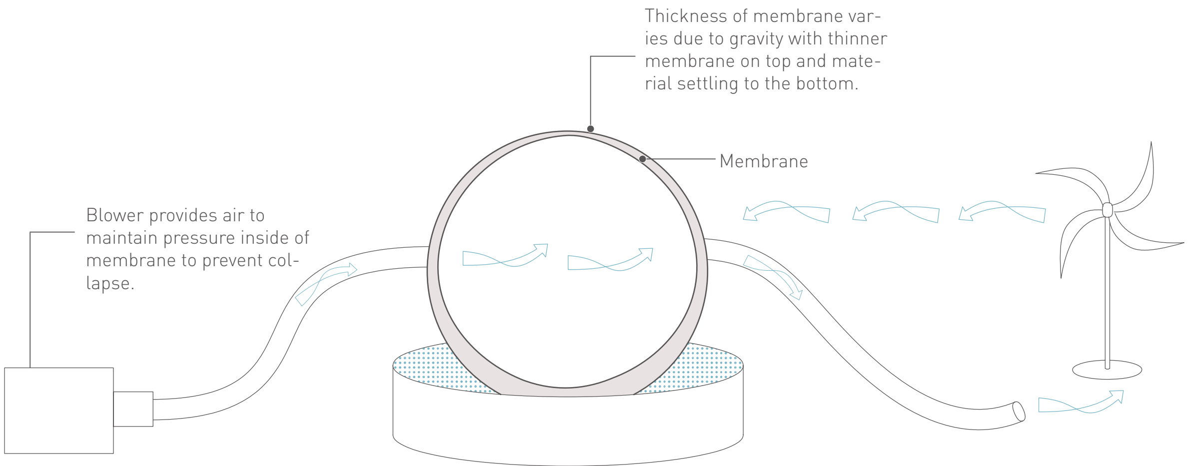
A critical difference brought about by the scale of this membrane was the issue of pressure. In order for the membrane to properly dry without collapse, a constant pressure had to be maintained inside the sphere. To accomplish this, two holes were cut on opposite sides of the membrane to allow for a blower to be installed. A blower was then run for three days to allow for the membrane to dry. After this point, the vinyl was slowly removed from the membrane until the entire installation was dried.

Opposite: Figure_3.11

Hypothetical Installation



Installation Set-up



Opposite: Figure_3.12

Figure_3.13

Opposite: Figure_3.14

Liquid as Environment

The use of biological membranes severally limits the context in which a design can be maintained. The most important restraint regarding membrane design is the need for a liquid environment. Without this crucial factor, all other considerations are moot. Practically, a site would have to consist entirely of liquid. Water becomes the new frontier for design. Contextually, liquid provides the means for both membrane existence as well as weightlessness.

There are numerous possibilities that facilitate a liquid environment on Earth. The most consuming being the ocean, followed by fresh water bodies and artificial basins. A system such as this could thrive in any of these environments given that certain conditions are maintained. The biological membrane will exist in liquid as long as it remains protected by a thin layer of oil or wax. However, in order for plant life to thrive, sunlight and chemical balance must be considered. This eliminates the deep trenches of the world's ocean. Seawater, however, does maintain a more buoyant environment than fresh water, mainly due to its salinity.

When physical restraints are considered, two different bodies of water are left: seawater and freshwater. Both of these bodies encompass different restraints and opportunities. Perhaps it is possible that the system can thrive in both environments and adapt to the conditions present.

Additionally, artificial liquid environments provide a possible environment for this architecture to inhabit. It would be close minded to only consider natural bodies of water as a possible site for such a new type of design. Much like NASA uses a specialized facility to conduct neutral buoyancy experimentation, this new system could conceivably exist in any liquid environment.

A Self-Sustaining Biosphere

With the ability to form membranes as well as grow plant life in them, a new biosphere-like habitat is created. These membranes posses the ability to hold liquid, furthering the possibilities of an underwater habitat.

Through the formation and integration of these systems, an environment can be created in which membrane acts as both enclosure and subsistence. A gelatin membrane can exist in a liquid environment, and within it contain a genetically different liquid habitat. Plant life grows from all directions, creating a three dimensional forest of sorts.

With the membrane existing in neutral buoyancy, due to the different chambers of membrane containing different density liquids, there is no tendency for aquatic plant life to favor any one direction. Growth forms with no intention of what is up and what is down. Liquid breathing becomes possible within these spherical forests. Aquanauts move from a traditional liquid environment into one that they can breath in without the aid of mechanical devices. Varying chambers may exist within the overall sphere, creating a sort of nuclei structure. The main membrane acts as the central habitat, with different sub-habitats existing within.

This system becomes completely self-sustaining. There exists no need for mechanical devices or degenerative materials. Food is produced, oxygen is provided.

Self-Sustaining Weightless Research Facility

With the unique aspects that are birthed from the plausibility of a weightless architecture, demand for such an environments becomes paramount. It is natural to feel the pull of a research based program to situate itself within such a new enclosure. The lack of restrictions that a both a liquid and weightless habitat provide pose unique opportunities to study both biological systems and further design possibilities.

Along with fewer physical restrictions, such a system provides a self-sustaining habitat capable of producing resources and re-generating and rather degenerating itself as to not to disturb the overall environment that surrounds it. The biological membrane is capable of growing plants in a unique three dimensional form. In addition, liquid breathing becomes both a useful tool for inhabitance and a means of further investigation of the phenomena.

Most importantly, such an environment allows for serious deliberation of weightless design, both biological and architecturally. Thus far, the only architecturally created 'blobs' are the result of recreation and intense structural analysis, they are not formed naturally. These forms are created in a weightless environment, the computer, but executed with gravity present. If these designs were taken to a weightless environment, a new means of construction is encountered; gravity becomes a non-issue.

The logical answer to the question of program becomes experimental. The system and design itself is an experiment within itself, why not execute experiments within the experiment. The biological membrane can be deployed when necessary in accordance with the user's specifications for research, and then naturally decompose when it is no longer needed. Once again, the habitat becomes a study in itself.

A biosphere of sorts is created, but not in the traditional sense. A liquid filled membrane exists within a larger liquid filled membrane, and then in another. Chambers are able to accommodate different environments as necessary. Plant life can either thrive or decay dependent on conditions present. A new research vessel is born.

Perhaps it is even possible that a program for such a new type of architecture has yet to be invented. It would only limit this new design to place a traditional program into such an experimental environment. As the system matures and develops, so will the program. The invention of such an architecture invite numerous opportunities for new programs, whether experimental or residential.

Human Adaptation to Liquid

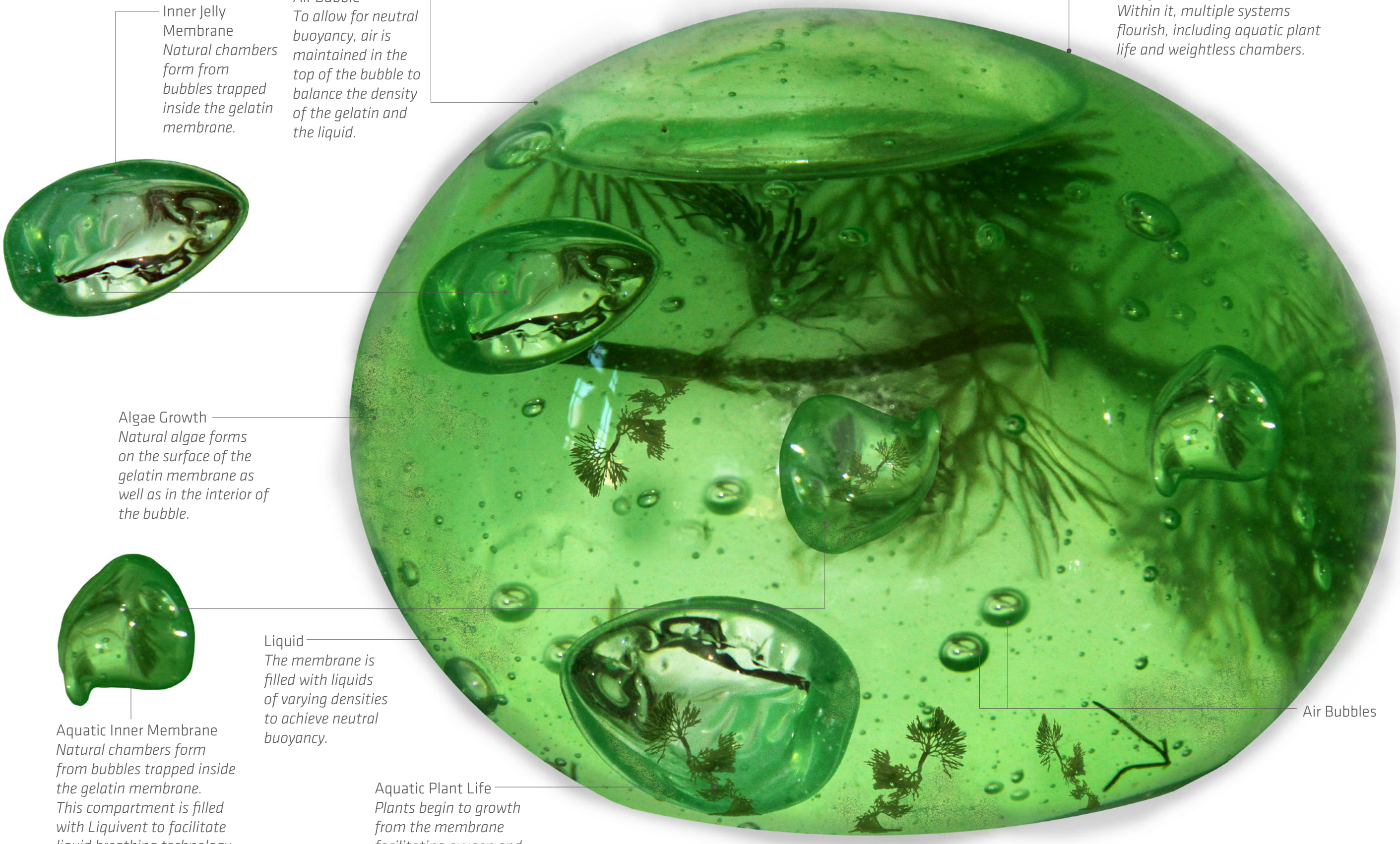
As the use of weightless liquid membranes becomes more ubiquitous, a new dawn will approach. This new architecture will not apart to human society, but human civilization will have to apart to an entirely new way of living. Humanity will eventually be confronted with the need to evolve to sustain such a system. No longer will the only livable environment be land based, liquid will open up an entirely new humanity.

Membranes with Liquid Chambers

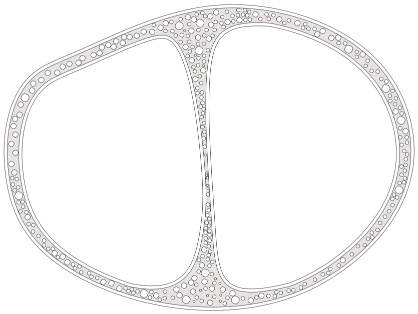
This new weightless biological architecture will take on an entirely new aesthetic from any architecture currently in existence.

Different programmable spaces are created within the biological membrane system through both the use of thin membrane 'walls and floating pods within the outermost membrane. These spaces are able to be filled with varying types of liquid as long as weightlessness is maintained. Plant life grows from membrane walls as needed and marine life coexists with human inhabitation.

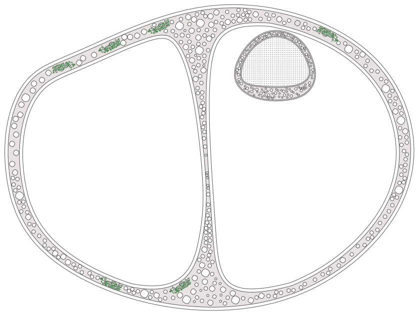
All membrane walls are self healing with no need for mechanical openings in order to facilitate movement.


Inner Jelly Membrane
Natural chambers form from bubbles trapped inside the gelatin membrane.
Air Bubble
To allow for neutral buoyancy, air is maintained in the top of the bubble to balance the density of the gelatin and the liquid.
Main Jelly Membrane
A large membrane is formed. Within it, multiple systems flourish, including aquatic plant life and weightless chambers.
Algae Growth
Natural algae forms on the surface of the gelatin membrane as well as in the interior of the bubble.
Liquid
The membrane is filled with liquids of varying densities to achieve neutral buoyancy.
Air Bubbles
Aquatic Inner Membrane
Natural chambers form from bubbles trapped inside the gelatin membrane. This compartment is filled with Liquivent to facilitate liquid breathing technology.
Aquatic Plant Life
Plants begin to growth from the membrane facilitating oxygen and food sources.

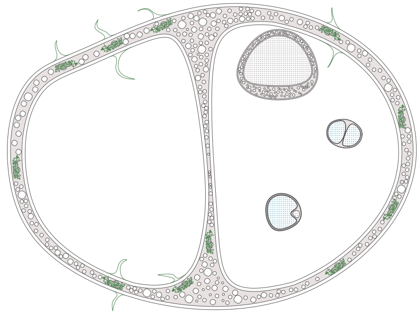
Full Lifecycle Development of a Membrane System



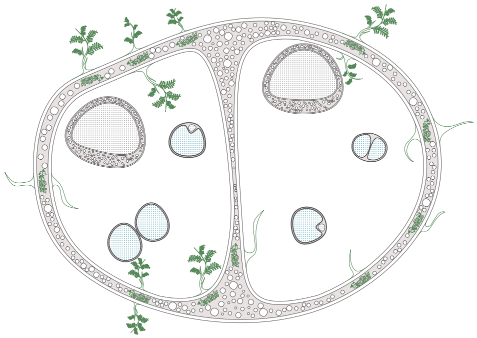
Initially, a thick gelatin membrane will be deployed. This membrane will be embedded with seeds and nurtriants in order to facilitate growth. This liquid filled membrane will act as the main membrane for the entire system.



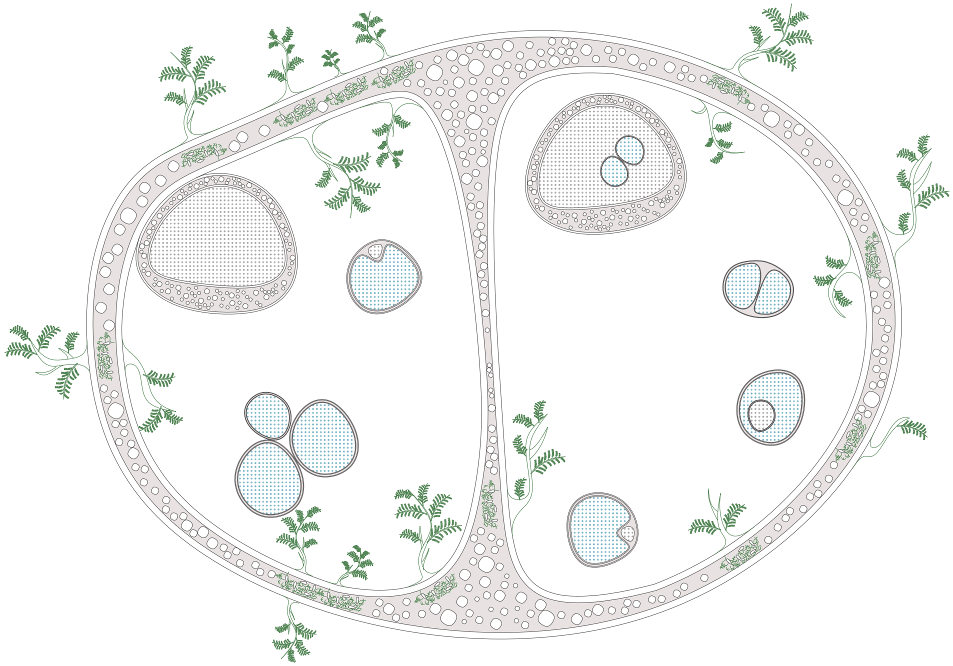
The seeds embedded in the membrane begin to grow and develop roots in the gelatin. An inner gelatin replication membrane is added and filled with air. This inner membrane will serve to populate the main membrane with individual research pods.



The inner membrane replicator produces membranes filled with the breathable fluid Liquivent. Plant life emerges from the membrane into the liquid environment.



Aquatic plant growth continues and flourishes. Unexpected growth, such as algae, also take to the membrane. More membranes are produced as the research center grows,



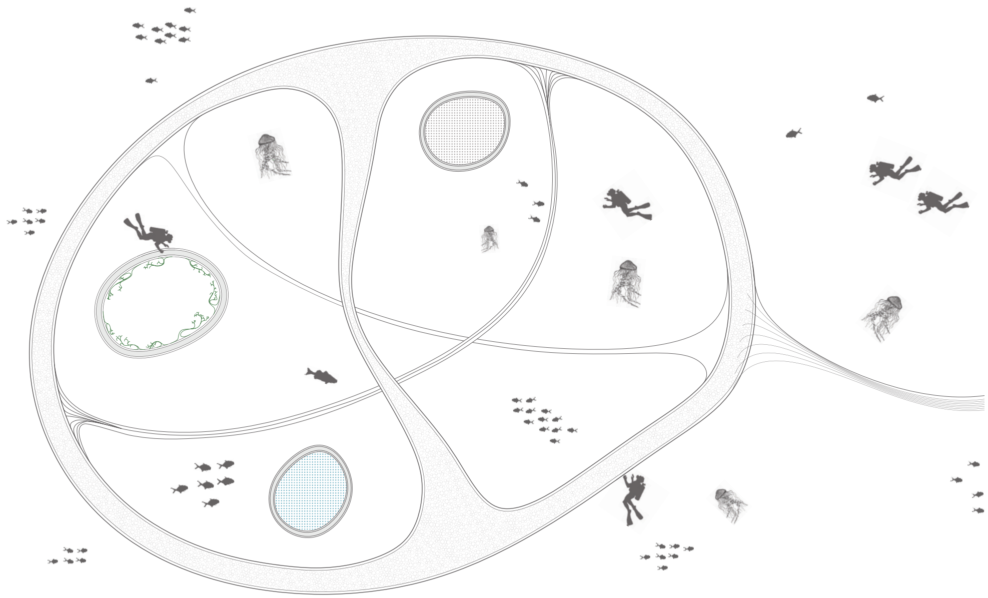
The weightless aquatic biosphere reaches maturity. Numerous inner membranes are present and plant life and aquatic life continue to develop. When individual membranes reach the end of their lifespan, they decompose into the environment and new membranes are created.

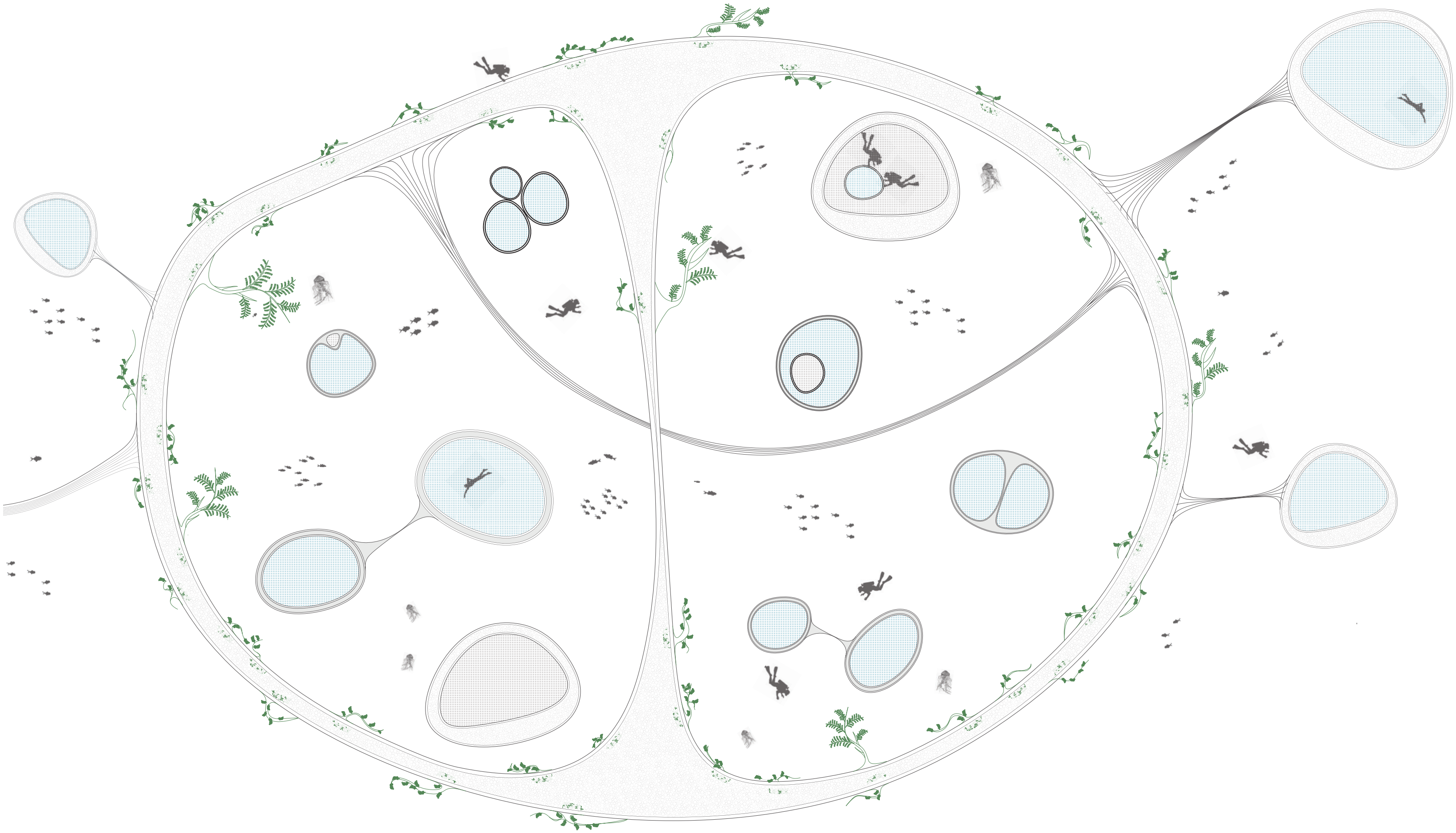
A Weightless Biological Architecture

The installation of such a weightless aquatic membrane is entirely experimental. Large membranes are formed which then house inner membranes to form a complex system of interacting chambers.

The process of entering and exiting this installation parallels that of the previous neutral buoyancy experiments. The membrane starts out floating on top of the water, at which points humans are able to entire the main membrane. As water is absorbed by the gelatin material, the membranes sink lower down into the body of water until it achieves a state of weightlessness. Experimentation takes place in this state until the gelatin membrane absorbs enough water to leave its state of weightlessness. At this point, the gelatin membrane is allowed to decay. As decay occurs, the membrane system becomes more buoyant, eventually floating to the surface of the body of water and allowing humans to exit the installation.

Within this system, a number of different functions and characteristics are present. Inner membranes are filled with varying liquids, some with water, some with the breathable liquid Liquivent. This allows different functions to be carried out. An aquatic farm is also present, which allows for both natural and imposed aquatic plant life to thrive on the gelatin soil. Exploration membranes allow for research to take place outside of the main membrane. Glowing plants and sea life provide a small source of light, as well as nutrition for the inhabitants.



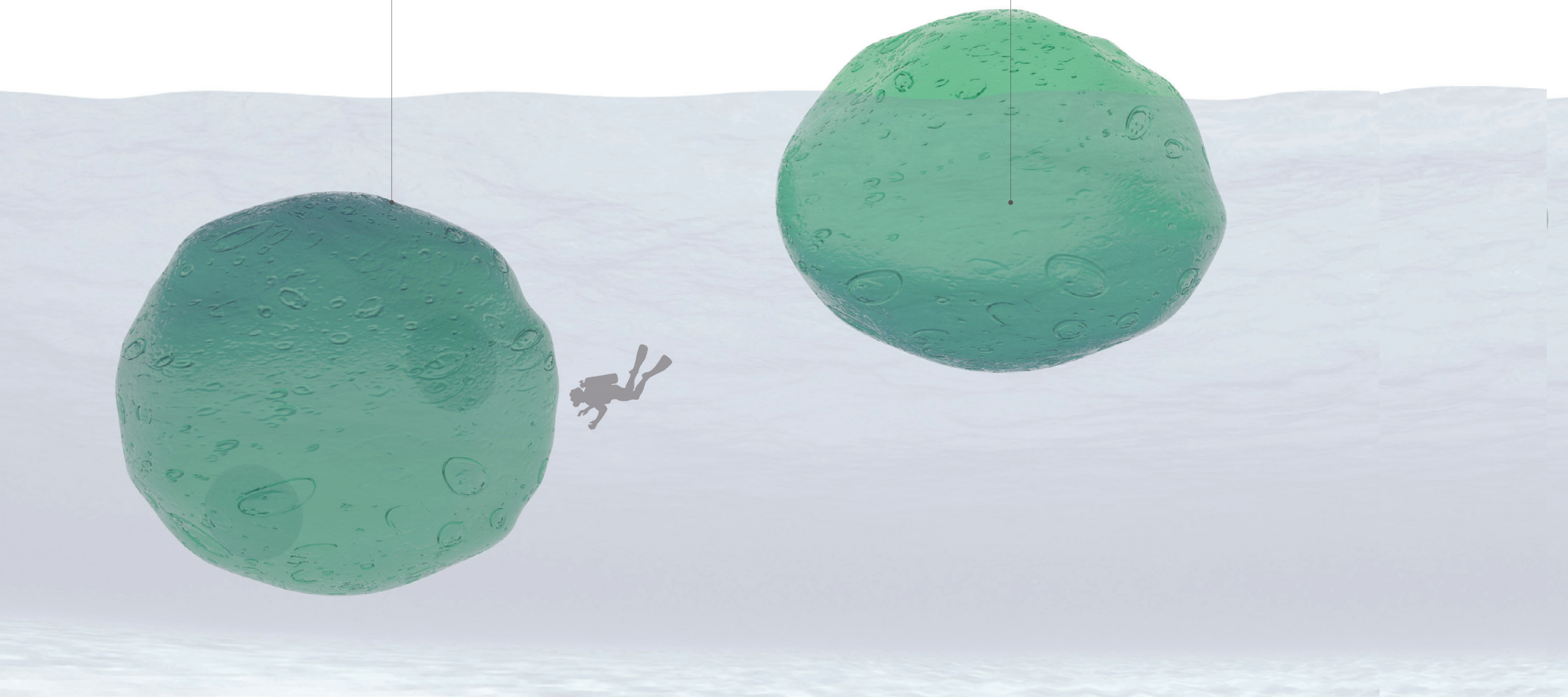


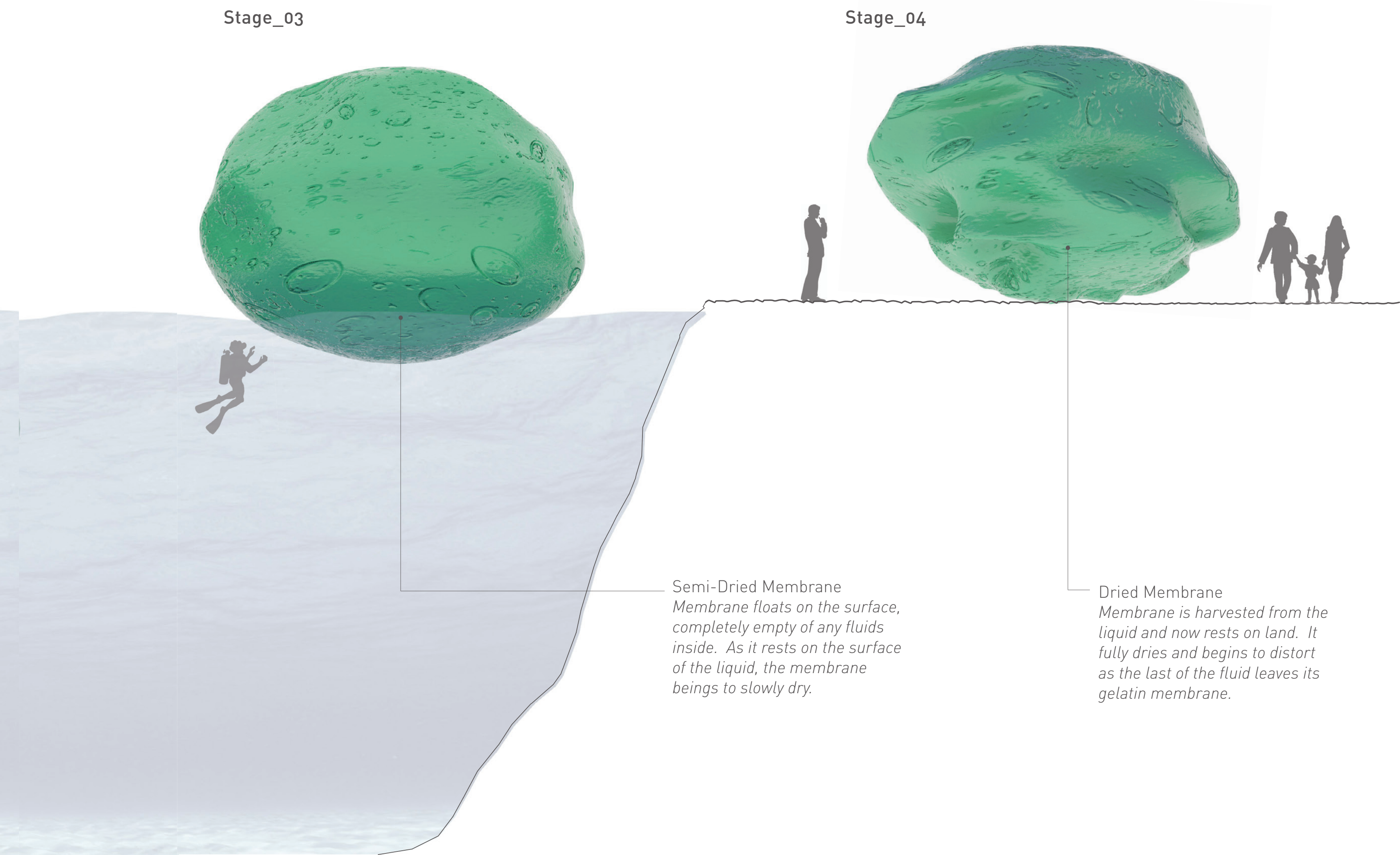
Stage_01

Liquid Membrane
A fluid filled membrane exists in liquid beneath the surface. Membrane is in a jelly state and has achieved neutral buoyancy.

Stage_02

Semi-Liquid Membrane
Liquid exists membrane and membrane exists its state of neutral buoyancy. Due to the decreased volume of liquid inside the membrane, the membrane begins to rise to the surface as gravity takes effect.




Stage_03
Stage_04
Semi-Dried Membrane
Membrane floats on the surface, completely empty of any fluids inside. As it rests on the surface of the liquid, the membrane beings to slowly dry.
Dried Membrane
Membrane is harvested from the liquid and now rests on land. It fully dries and begins to distort as the last of the fluid leaves its gelatin membrane.

Life in Liquid: A New Existence

The possibilities allocated by a new weightless biological architecture are too immense to speculate. With gravity absent and biological polymers used as building method, an entirely new human existence is birthed. Much like humans have evolved to flourish on land, a return to liquid would completely revitalize human existence.

The way architecture is viewed in this new liquid future will be immensely different from anything seen today. This approach will radicalize the very practice of architecture, forcing a new method of thought and construction. We will no longer design, build, and inhabitant the world as we currently do.

The change in system from that of concrete, mechanical design to a free liquid based system will provocate immense possibility for the progress of architecture. Architecture will be completely overhauled into an art that favors radical, biological based design. While currently design has come to exist in the computer, this change to a weightless liquid environment will finally allow digital geometry to become reality.

In current practice, to only way 'blobs' are able to be constructed is through the use of complex digital technologies and intricate construction practices. This type of architecture becomes effortless when placed into a liquid environment. No longer is the computer the only realm in which this design can exist at ease.

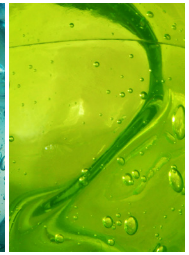
Additionally, the ability for this new architecture to provide food, shelter, and life in one complete system is key to its survival. There presently exists no architecture that can both encompass its inhabitants while also becoming part of the environment around it. An architecture that can become part of its landscape as well as provide food is the future.

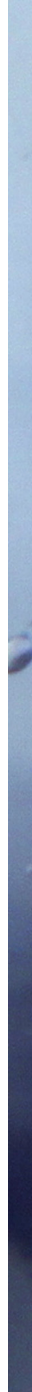
The results and insight gained throughout the experimentation of this thesis demonstrates the feasibility of such a future. It is entirely possible that one day we will all be living in a liquid realm. The future will not mimic any type of design currently seen today, but revolutionize the way we think and build.

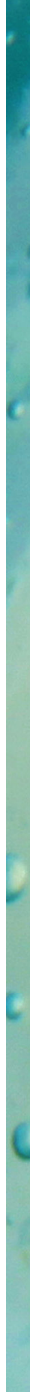
The future of life lies in liquid...

Appendix 1:

Images





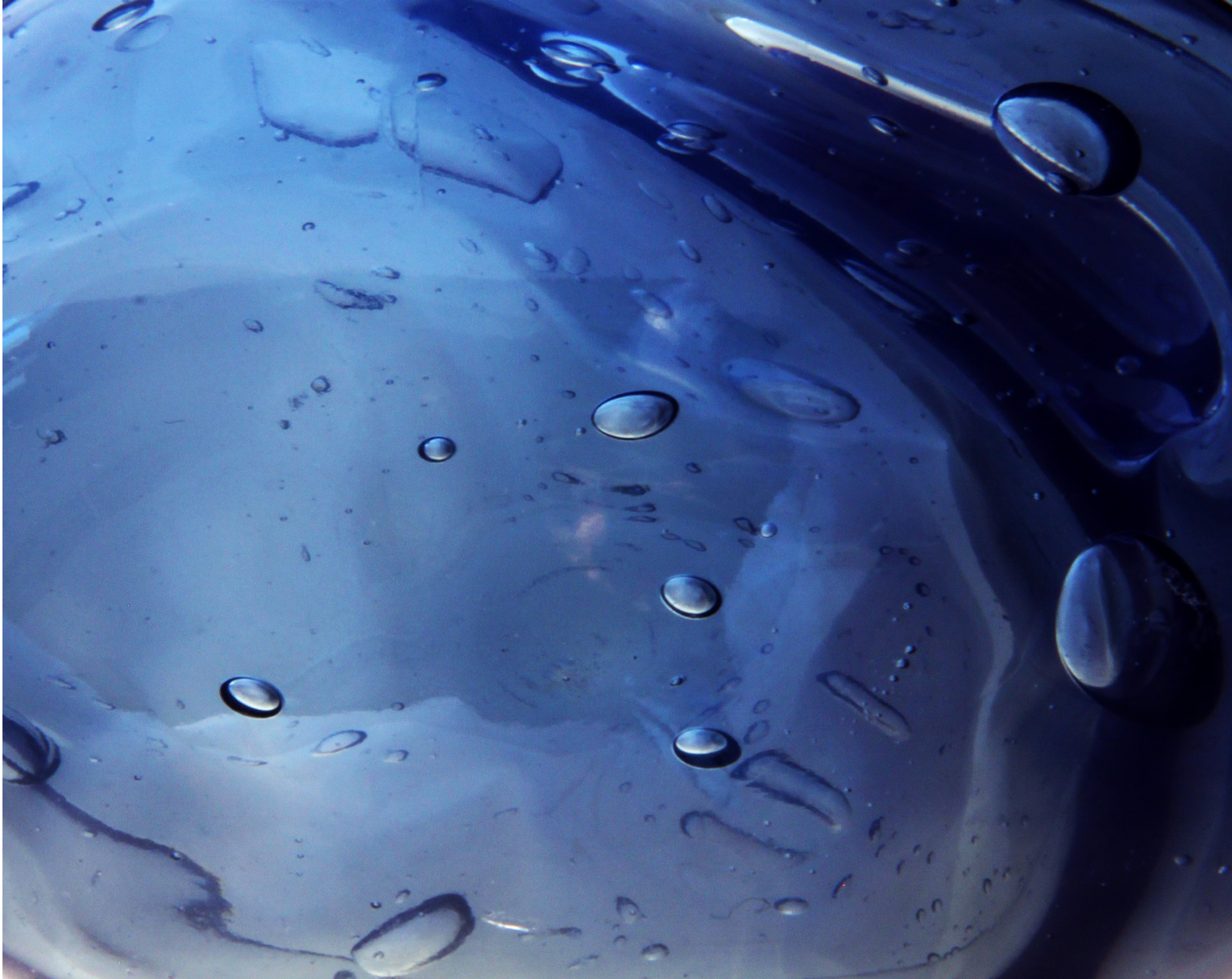


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Figure_1.4: *Hussain, Farooq. Living Underwater. [New York]: Praeger, 1970. Print.*
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Appendix: *Julie Solomon, 2011.*

Figure: Archigram

During the height of modernity, Archigram drew much inspiration from maritime activities, examining research vessels such as SEALAB along with others in order advance the architectural discipline. Examples of this fascination with underwater environments includes Kikutake's Marine City, Buckminster Fuller's Underwater Island (1963) and Warren Chalk's Underwater City Project (1964). The technological advances necessary to build in an underwater environment resonated with Archigram's need to design for the future and push the discipline farther. Water provided an unknown environment along with unpursued opportunities and challenges. With Archigram's push for futuristic technologies and machines along with an abundance of experimentation, the ocean provided a much needed new frontier, untapped by other designers. In 1962. Cousteau's Precontinent experiments were executed. This helped to fuel an interest in underwater architecture. These experiments included aquanauts, also examined by Farooq Hussain in his text "Living Underwater." The concept of humans being sustained underwater for long periods of time was not a new concept, but one of the first times to be executed successfully. The exploration of the sea as a possible human environment was paralleled by the Metabolist Movement in Japan during the same time period.

Raisbeck, Peter. Marine and Underwater Cities 1960-1975. Brisbane: SAHANZ, 2002

Figure: Maria Paz Gutierrez, Department of Architecture UC Berkeley

Maria Paz Gutierrez researches material bio-responsivenss and the way in which it effects sensorial, cultural and biological phenomena. Her current work includes researching hydro-responsive membranes and authoring a book on biometric material systems. One of her recent projects was entitled "Material Bio-Intelligibility." This project emphasizes characteristics of life, including self-organization, adaptability, regeneration, and decomposition. She used parametrics as a vehicle for researching biological self-organization and replication. Gutierrez appears to be very invested in exploring actual biological processes and the networks and organization than govern them. She places a great deal of emphasis on natural systems and the intricate network created by such systems. She focuses on true biological hierarchy,rather than pure bio-mimcry, with cell design driving a lot of the aforementioned project.

Faircloth, Billie, Kiel Moe, and David Gissen. ACADIA 08: Silicon Skin : Exhibition : Exhibition Catalog of the 28th Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA). [United States]: Association for Computer-Aided Design in Architecture, 2008. 278-85. Print.

Figure: Farooq Hussain

In Farooq Hussain's book "Living Underwater" the history of human's quest to inhabit liquid environments is explored. He begins with human's first underwater exploration using the aqualung, and how that preceded further more complex research initiatives underwater. Hussain also notes the important difference between the lung of a human and the gill of a fish, and how oxygen intake is used in a similar fashion, however there are marked differences between oxygen found in water and oxygen in air. This concept is also explored through NASA and the US Navy, namely the SEALAB research vessels. The concept of underwater habitats, mostly in the form of research centers, also relates to this position. Presently, the only inhabitable underwater designs are for research purposes, however, this has been evolving into underwater lodges for civilian use. Like many others that explore underwater inhabitation, Hussain positions himself as pro-water. He believes that humans underwater is indeed a definite possibility. It is important to note that his text was published in 1970 during which modernity and Archigram were ending their presence. A great deal of design work was done concerning the marine city. It can be assumed that Hussain both read and critiqued this work.

Hussain, Farooq. Living Underwater. [New York]: Praeger, 1970. Print.

Figure: Metabolist Movement

The Metabolist Movement began in Japan in the late 1950's. It consisted of a group of young architects and designers. These designers' focus consisted of exploring possible solutions to urban problems in an innovative way, mainly through industrial rather than architectural means. Unlike Archigram, the Metabolist group did not rely on architectural principals. In 1961, member Kiyonori Kikuatke presented his project "Marine City" at the "Visionary Architecture" exhibition at the Museum of Modern Art in New York. The move the water represented a new approach to urban design, consisting of more flexible structures and societies than those presently residing on land. Mass production was emphasized, similar to in the text "Climbing Mount Improbably" where a super computer's sole purpose is replication efficiency, like in most biological systems. Kikutake spent a great deal of time researching ocean engineering and construction techniques to make the possibility of water design a feasible solution to current problems, mainly a lack of physical space to build. However, this proposal was critiqued for its lack of concern for preserving natural systems and the environment. Most notable of this project is that it is floating rather than submerged, dissimilar to Farooq Hussain's request for true underwater inhabitation.

"Metabolist Movement between Tokyo Bay Planning and Urban Utopias in the Years of Rapid Economic Growth 1958-1964 ". 03 October 2010.<http://dspace.wul.waseda.ac.jp/dspace/bitstream/2065/28739/3/Honbun-4554.pdf>.

Figure: Phil Pauly

Phil Pauly is a UK based designer responsible for the design of Sub Biosphere 2. His main interest lies in marine habitats and organic forms and designs. One notable quote of his states "If life were a computer system attempting to recreate its own creation, what would it create?" His research includes a Global Marine Research Program which emphasized the design and implementation of self-sustaining underwater habitats in today's society. This biosphere would be inhabited by aquanauts, tourists, and oceanographic life sciences. The design includes a series of attached spheres. The entire system can either float on water or be completely submerged. He places a great emphasis on the sustainability of these habitats. The entire design can sustain all life support systems (air, water, food, electricity, etc). Unlike many other designs for the ocean, Pauly's creation stands out as one of the only that is meant to be submerged, fully exposing itself to the atmospheric and pressure challenges of such a site.

Phil Pauley - Home. Web. 03 Oct. 2010. <http://www.philpauley.com/index.html>.

"Sub Biosphere 2: A Self-Sustaining Underwater City | Inhabitat - Green Design Will Save the World." Green Design Will save the World | Inhabitat. Web. 03 Oct. 2010. <http://www.inhabitat.com/2010/06/16/sub-biosphere-2-a-self-sustaining-underwater-city/>.

Figure: James Cameron

James Cameron has spent many years making films that explore alternate types of worlds. A technique called liquid breathing exists and allows humans to take liquid into their lungs, therefore breathing underwater. While this is only used for government purposes, it has been explored in pop culture as well, namely the film "The Abyss." In the science fiction film "The Abyss", the concept of liquid breathing is explored as a means of diving to otherwise impossible depths. The first instance of this is seen when a scientist uses a rat to demonstrate the possibility of an otherwise air-breathing animal to breath *liquid. The rat is completely submerged and at first appears distraught due to the change. As the rat's anxiety from being forced underwater grows, it slowly begins to adjust to its new environment. Slowly, the rat begins to take the liquid into its lungs. As this transition takes place, the rat becomes more and more calm with the change. Once the rat has calmed down and adjusted to the change in pressure, the rat begins to breath the liquid as it would normally breath air. Later in the film, a creature formed completely of water appears to the characters. This creature has an underwater world created deep in the ocean. It is decided that a human will dive using the liquid breathing technique originally tested on the rat. A man is placed in a dive suit with a spherical glass helmet covering his head. This helmet is filled with liquid that he at first resists and then slowly takes into his lungs and breaths with ease. Using this technique, he is able to dive to levels otherwise impossible. This technique does not exist only in science fiction, as it has come to be proven by science. The worlds that James Cameron creates in his film parallels the scientific world. Both liquid breathing and underwater habitats have been explored extensively in both the architectural and scientific worlds.*

Avatar.Dir. James Cameron. 20th Century Fox, 2009. DVD.

The Abyss.Dir. James Cameron. 20th Century Fox, 1989. DVD.

Figure: Richard Dawkins

In Richard Dawkin's book "Climbing Mount Improbable" the notion of rapid replication, mainly of DNA, is explored. Dawkins explains his notion of a super computer, "The Robot Repeater",which replicates in the same fashion as genetic material. He also divulges into an exploration of replication in nature and the way that natural systems generate themselves in computational ways. Dawkins takes note of the similarity between computer and DNA viruses and the way in which they duplicate themselves. This super computer would replicate in such fashion, creating an automated system that knows how to both copy and assemble. Dawkins examines how when earth first formed, with no life, no biology, only physics and chemistry, something, in this case a molecule, had to possess the ability to replicate. This is what created life, and therefore biological systems. These molecules formed bacteria and those formed the eucaryotic cell. Without the ability to replicate, life would cease the exist. This notion of replication is seen throughout most biological design studies. Even designers who purely research bio-mimcry still utilize the concept of replication.

Dawkins, Richard. "Chapter 9: The Robot Repeater." Climbing Mount Improbable. New York: Norton, 1996. Print.

Figure: George Jeronimidis

Professor George Jeronimidis, University of Reading, researches the topic of biomimetics in relation to smart materials and structures. This type of biological mimicry is wide spread throughout the bio-design field, both architecturally and concerning other topics. The use of natural systems and processes aids in the design of new products which in themselves are not necessarily biological. Jeronimidis uses biological processes to examine plant and animal biomechanics, smart materials and structures, and the mechanics of composite materials and structures. Some of his projects have included a composite-related designs for smart, self-regulating composite wind turbine blades and the design and development of composite flywheels for hybrid urban mass transport systems.

"ACADIA 2008: Silicon Skin » Blog Archive » George Jeronimidis." ACADIA Home Page. Web. 03 Oct. 2010. <http://www.acadia.org/acadia2008/?p=18>.
"Professor George Jeronimidis - University of Reading." University of Reading Top Ranking

University for Research. Web. 03 Oct. 2010. <http://www.reading.ac.uk/cme/about/staff/g-jeronimidis.aspx>.

Figure: NASA

Neutral buoyancy describes the phenomena in which an object has an equal tendency to float and sink, making the objects appear as if it is weightless, or hovering. To make something neutrally buoyant, a combination of weights and flotation devices are used. This is similar to objects in orbit. However, it is important to note that the object, if living, can still feel and sense his or her weight, unlike in low gravity situations. Also, unlike in orbit, the creature still experiences the drag of the surrounding water or liquid, making it more difficult to move. Due to neutral buoyancy's similarity to reduced gravity conditions, it is utilized for EVA, or Extravehicular Activity, training among astronauts. The sensation of being weightless is used to allow astronauts to prepare for trips into space. Like stated previously, there are some limitations to this method, including water drag and the ability to sense one's true weight. The technology of neutral buoyancy progresses man's ability to survive underwater and the possibility of underwater inhabitation.

"NASA - Neutral Buoyancy Lab." Untitled Document. Web. 03 Oct. 2010. <http://dx12.jsc.nasa.gov/site/index.shtml>.

Figure: Sarah Jane Pell

Sarah Jane Pell, PhD is an artist and practive-based performance researcher as well as professional diver that explores underwater environments and the technology necessary for such designs to exist. Many of her projects examine the behavior and limits of humans in extreme environments. Her projects include research into neutral buoyancy and aquabatics. Aquabatics is a form of performance art in which psychological states and physical conditions are explored by inhabiting an aqueius environment. He project "Hydromeduda: Undersea to Outer Space" strives for the design of a "wearable, self-contained aqueous architecture for us by humans in weightless environment training (WET) conditions." Pell's projects and research go straight to the source: water. She fully examines what it means to inhabit an underwater environment, both psychologically and physically, a concept that is yet to be fully explored.

Dr Sarah Jane Pell | Artist - Researcher - Commercial Diver - SciArt Collaborator - Public Speaker - TEDFellow - Atlantica Crew. Web. 03 Oct. 2010. <http://www.sarahjanepell.com/index.html>.

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