TEAM 11: MEMO 2

TUBE ANEMONE


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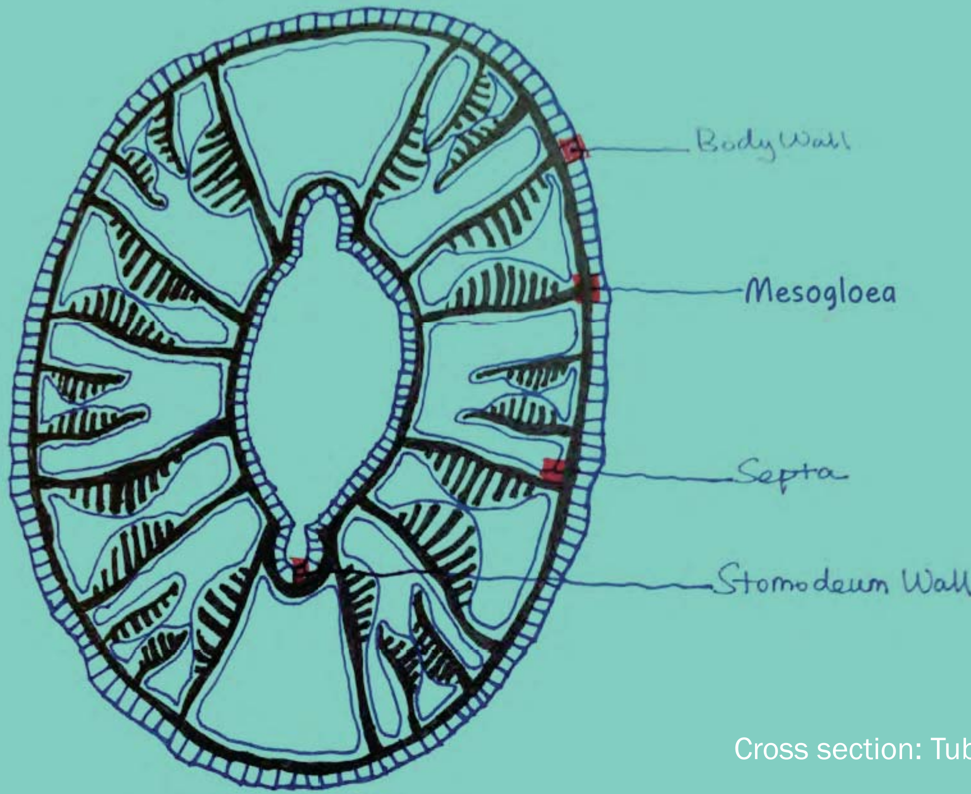
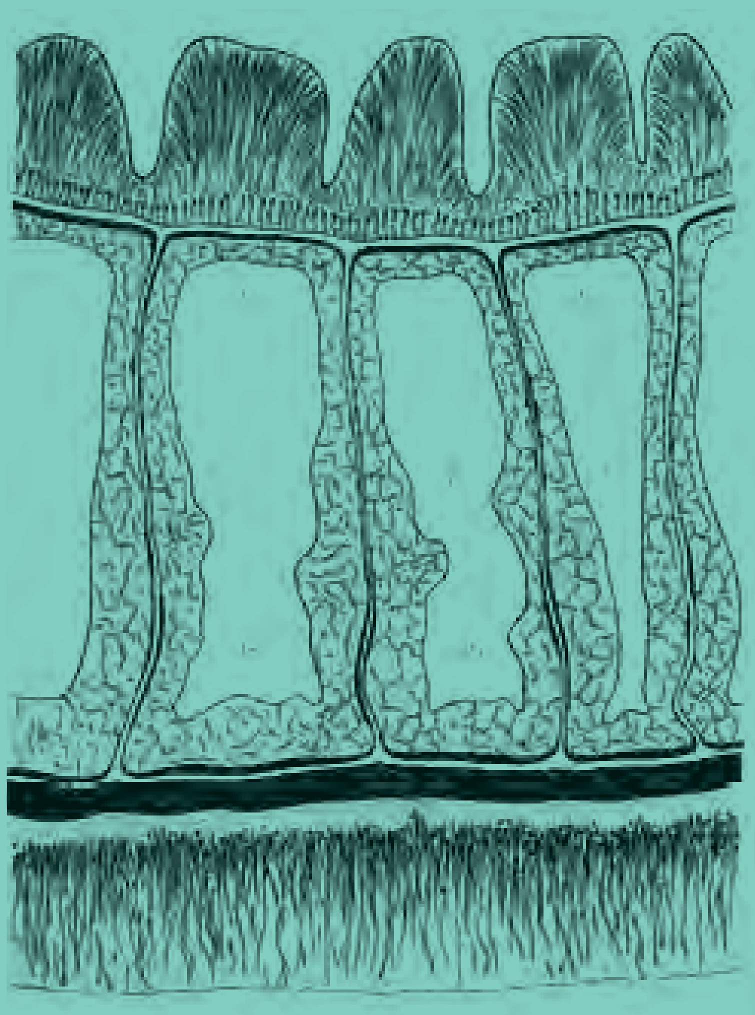


Cross section: Tube anemone



Detail: Muscle wall structure

1

RESEARCH FINDINGS

MUSCULAR STRUCTURE

Tube anemones (often referred to by their Order designation, Ceriantharia) are solitary invertebrate water-dwelling predatory animals that create tube-like structures in which they live. They maintain the circular form of their soft, sack-like bodies by regulating internal water pressure. Tube anemones are ammonotelic (excrete nitrogenous waste in the form of amonia). Diffusion across the body and tentacle surface eliminates the ammonia from the body.

Generally tube anemones are nocturnal animals, remaining in their tubes in order to avoid light. They also withdraw into their tubes to seek protection, since they lack the sphincter muscles needed to retract their oral disk or withdraw their tentacles. Their primary predators are organisms that exhibit a resistance to the effects of their stinging cells, such as the dendronotid nudibranchs that latch onto and ingest the tube anemone's tentacles.

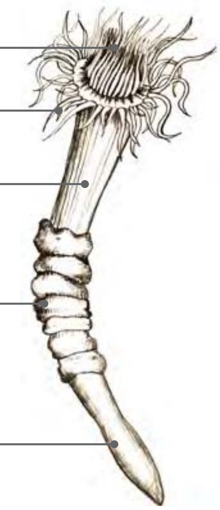
THE TUBE

Ceriantharia tubes are composed of a fibrous material which is made from mucus (secreted from gland cells of the column ectoderm) and threads of namatocyst-like organelles known as ptychocysts (specialized cnidae – the stinging cells of all cnidarians). The tube is reinforced by foreign objects (such as grains of sediment). The tube may be as long as 1 meter (3.3 feet), and is longer than the anemone that resides in it.

EXTERNAL ANATOMY

The tube anemone body is basically a tapering cylindrical column (maximum 3 cm diameter and 40 cm length) with a crown of tentacles and oral disc at one end (the oral end) and a "foot" at the other (aboral) end. There is a marked decrease in the thickness of the body-wall and especially of the muscular layer, toward the aboral end. The oral end exhibits greater sensitiveness to tactile and other stimuli, and greater contractility of the muscles of this region when stimulated.

The oral end terminates in an oral disc, which contains a slit-shaped mouth in its center. The aboral end terminates in a blunt point (foot) in which a small hole exists. The hole is used as a means for water to escape the distended animal during retraction into the tube. The column (main body) is hollow and contains the coelenteron (gastrovascular cavity).



Tube Anemone Diagram

The tentacles are hollow evaginations (out-foldings) of the body wall and contain extensions of the coelenteron. Their epidermis contains cnidocytes used for stinging either prey or predators. Tube anemones have two distinct whorls of tentacles on the oral disc. The outer whorl consists of large tentacles that extend outwards. These outer tentacles are used primarily in prey capture and defense. An inner ring or shorter "labial" tentacles surround the mouth and are used primarily for prey manipulation and ingestion. In many species the tentacles can be bioluminescent, which could be a visual "startle" defense against predators that may attack. The outer tentacles can grow up to 20 cm in length and can reach up to one foot in diameter when fully extended.

INTERNAL ANATOMY

Tube anemones are diploblastic, having two cellular layers separated by a jelly-like mesogloea in which skeletal elements can occur. The column wall (body wall) of the tube anemone is comprised of three layers of tissue: the ectoderm, the endoderm and the mesogloea.

The ectoderm or epidermis (outer layer) is composed of cells and muscular and nervous elements. The majority of the ectoderm's cells are elongated columnar cells (epithelio-muscular cells), which contain a nucleus and have cilia at their ends. Other types of cells found in the ectoderm include gland cells, sense cells, and cnidoblasts (which produce the "thread cells" or nematocysts).

The endoderm or gastrodermis (inner layer) is also comprised mainly of epithelio-musculer or myo-epithelial cells. It also contains gland cells and nervous elements.

The mesogloea layer (middle layer) is not a cellular layer, but a gelatinous substance secreted by the endoderm and ectoderm. Frequently cells will migrate from the ectoderm and endoderm into the mesoglea.

The mouth is an elongated slit in the center of the oral disc. The mouth is slightly expanded at each end. These expansions are the ends of vertical, ciliated grooves called siphonoglyphs. The cilia of the siphonoglyphs generate a constant flow of water into the coelenteron even when the mouth is closed. This maintains a positive hydrostatic pressure in the cavity and helps keep the column distended. The mouth opens into a short, flattened tube – the pharynx (throat). The pharynx leads into the coelenteron.

The coelenteron is partitioned by mesenteries that expand the inner absorptive surface. Mesenteries are longitudinal sheets of tissue that extend radially from the column wall to the actinopharynx. These “infoldings” of the endoderm and mesoglea extend from the body-wall into the gastrovascular cavity. The number of mesenteries also decreases toward the aboral end, until only a single pair remains; all new mesenteries appear first at the oral end and extend gradually aborally, thus indicating that growth in circumference begins orally.

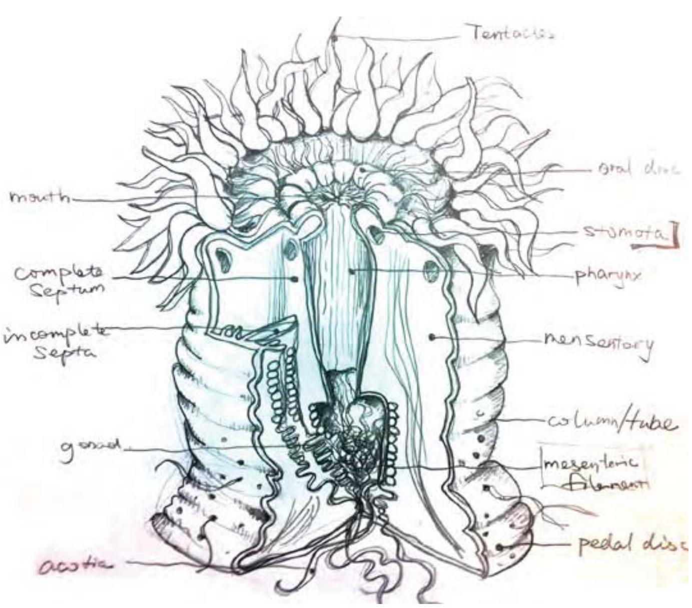
Free edges of the mesenteries bear structures that are termed acontioids (adhesive threads). Covering each surface of a mesentery is a sheet of flagellated epithelio-muscular cells. Between these two endodermal epithelio-muscular layers lies a fibrous mesogloea, similar to the mesogloea layer within the column wall. The function of mesenteries is to increase the surface area for respiration, digestion and uptake of nutrients. They also provide structural support. Attached to one face of each mesentery is a layer of longitudinal retractor muscle.

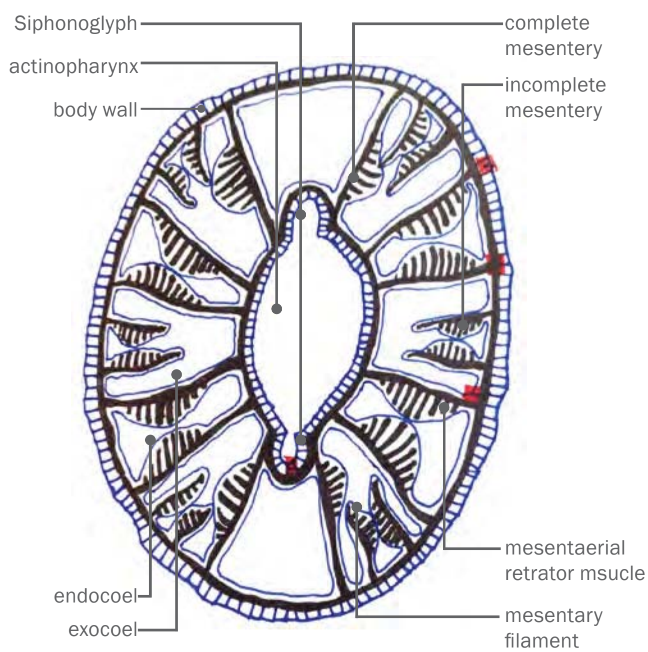
EXPANSION, CONTRACTION AND FLUID DYNAMICS

The expansion and contraction of the anemone within its tube is due to the vertical movement of these longitudinal retractor muscles. Even though these muscles react in a vertical direction, they create an inner force or tension within the body of the anemone that stretches the column wall taut and enables the tube anemone to retain its circular form when the digestive cavity is filled with water.

The expansion and contraction is integrated with the hydraulic pressures of the water that flows through the body as it distends and contracts. It uses water pressure to regulate its form in response to environmental and external stimuli. The inability of the animal to extend to its full length without the aid of water-pressure is due to the absence of circular muscles in the body-wall. Extension is passive, not active. The accumulation of water in the column appears to be the result of diffusion through the walls, and especially through the very thin membranes at the oral and aboral ends.

When undisturbed, the body and tentacles are usually more or less distended with water and the body-wall is always tense – under high amounts of pressure. If the body of a distended anemone is opened quickly by a small cut the water issues with considerable force. When a tube anemone contracts rapidly the water squirts from the aboral foot with great force.





Tube Anemone Cross Section

Below are some interesting notes about tube anemone expansion and contraction from C.M. Child's scientific investigations of tube anemones:

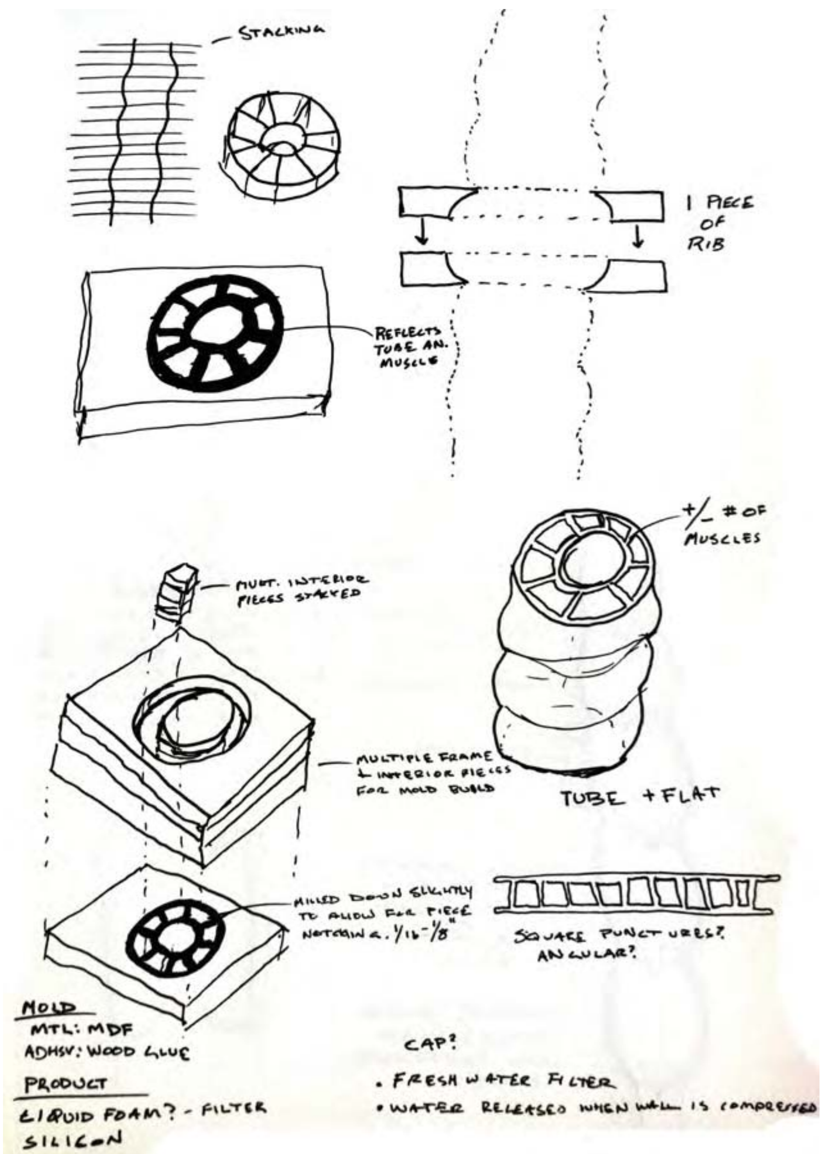
- When the body is distended the œsophagus, with the exception of the siphonoglyphe and perhaps some grooves and crevices, must be closed.
- When contraction occurs the water first issues from the aboral pore; then when the pressure is sufficiently reduced to permit it, the œsophageal walls are separated by muscular action and the remaining water issues from the mouth, often accompanied by mesenterial filaments. Thus the oesophagus is widely open only during extreme contraction.
- The cilia on the endodermal surface of the body-wall produce a current flowing orally in each mesenterial chamber. The water passes from each chamber along the aboral face of the marginal tentacle, back on its oral face beneath the disc toward the stoniodaum, probably into and out of the labial tentacles and aborally along the stomodaum. In all probability cilia along the sides or margins of the mesenteries force it further aborally.
- The internal water-pressure plays a large part in form-regulation in Cerianthus. The general pressure affects the rapidity of growth wherever it may be taking place and it is possible that the local pressure exerted on the body-wall by the currents passing orally in each mesenterial chamber is the formative stimulus for the marginal tentacles.
- Regeneration of tentacles is impossible unless mesenteries are present. The reason suggested for this is that in the absence of mesenteries there is no localization of the currents corresponding to the intermesenterial chambers, and, moreover, the water being unconfined between mesenteries, exerts less pressure on the inrolled oral end than if mesenteries were present.
- Local retardation or inhibition of tentacle-regeneration can be brought about by preventing distension of a part or parts of the oral region.

ITEMS OF ADDITIONAL INTEREST:

Regeneration: The rapidity of regeneration is dependent on the position which the anemone section occupied in the parent body, a decrease in the rapidity of regeneration occurring with increasing distance from the oral end. The effect of position has a similar impact on rapidity. Not only is there a decrease in the rapidity of regeneration toward the aboral ends, but the total amount of oral or aboral regeneration also decreases in the same manner.

Opacity: The pigmentation of the body is closely connected with the presence and arrangement of the muscular layer. When the muscle layer is thick, or under less tension, it become more opaque. When it is under tension, either from internal water pressure, or due to the regenerative or growth processes, the column wall becomes more translucent.

Tube Anemone: expansion and contraction diagram


STACKING
1 PIECE OF RIB
REFLECTS TUBE AN. MUSCLE
+/- # OF MUSCLES
MULT. INTERIOR PIECES STACKED
MULTIPLE FRAME & INTERIOR PIECES FOR MOLD BUILD
TUBE + FLAT
MILLED DOWN SLIGHTLY TO ALLOW FOR PIECE NOTCHING. 1/16-1/8"
SQUARE PUNCTURES? ANGULAR?
MOLD
MTL: MDF
ADHSV: WOOD GLUE
PRODUCT
LIQUID FOAM? - FILTER
SILICON
CAP?
• FRESH WATER FILTER
• WATER RELEASED WHEN WALL IS COMPRESSED

2 WORKING HYPOTHESIS

Team 11's working hypothesis is that the essence of the tube anemone's expansion and contraction motion can be applied to model form, and ultimately to the built environment, as a system of interdependent processes rather than in one-dimensional mechanisms. Rather than looking at expansion and contraction as an isolated process, it is viewed as part of a complex system of self-regulation that is dominated by hydrostatic pressure.

DISCOVERY

The tube anemone uses a combination of passive and active strategies to respond to its environment. The passive aspect involves diffusion and circulation. The active aspect involves the voluntary contraction of the tube anemone's strong longitudinal retractor muscles and subsequent expelling of water.

The physical properties of the muscles themselves, in combination with the constant force of internal water pressure, dictate the tube anemone's self-regulation and allow it to maintain a state of equilibrium in its constantly changing environment.

EXPERIMENTATION

Team 11 sought to translate the essence of the tube anemone's motion into model form through experimentation with, and exploration of, various materials and mechanisms.

The model exploration of the expansion and contraction process focused on three (3) areas of the tube anemone's anatomy and biological processes:

1. The vertical motion of the longitudinal reactor muscles, which creates tension across the surface area of the column wall.
2. The build-up of hydrostatic pressure within the anemone and its subsequent release through the opening in the aboral foot (and oral disc).
3. The variations in the density and opacity of the porous column wall due to tensional fluctuations.

In exploring motion the team studied a variety of mechanisms that are reminiscent of the tube anemone's longitudinal retractor muscles. The basic concept was expanded by including axis transfer (shifting motion from horizontal to vertical movement) and looking at different types of joint movements.

To demonstrate the integral relationship between muscular action and hydrostatic pressure, additional studies were made into systems that have the ability to detect internal pressure levels and have mechanisms or valves that allow the systems to release pressure at a certain levels and reset. These systems could also be activated by external triggers, such as light, heat, or humidity that enable them to respond to changes in the surrounding environment.

Research revealed a direct connection between membrane opacity and surface tension. Exploration was made into materials that could exhibit fluctuations in opacity/transparency in response to changes in ambient heat, light, humidity or direct pressure (tension). One of the materials that proved promising during the course of research is silicone (both in sheet form and moldable form). Another avenue of exploration involved multiple-layered skin systems, with a liquid or gel middle layer that could demonstrate variations on opacity, color, and/or luminescence.

APPLICATION

Potential architectural applications of the results of research and model exploration include the following:

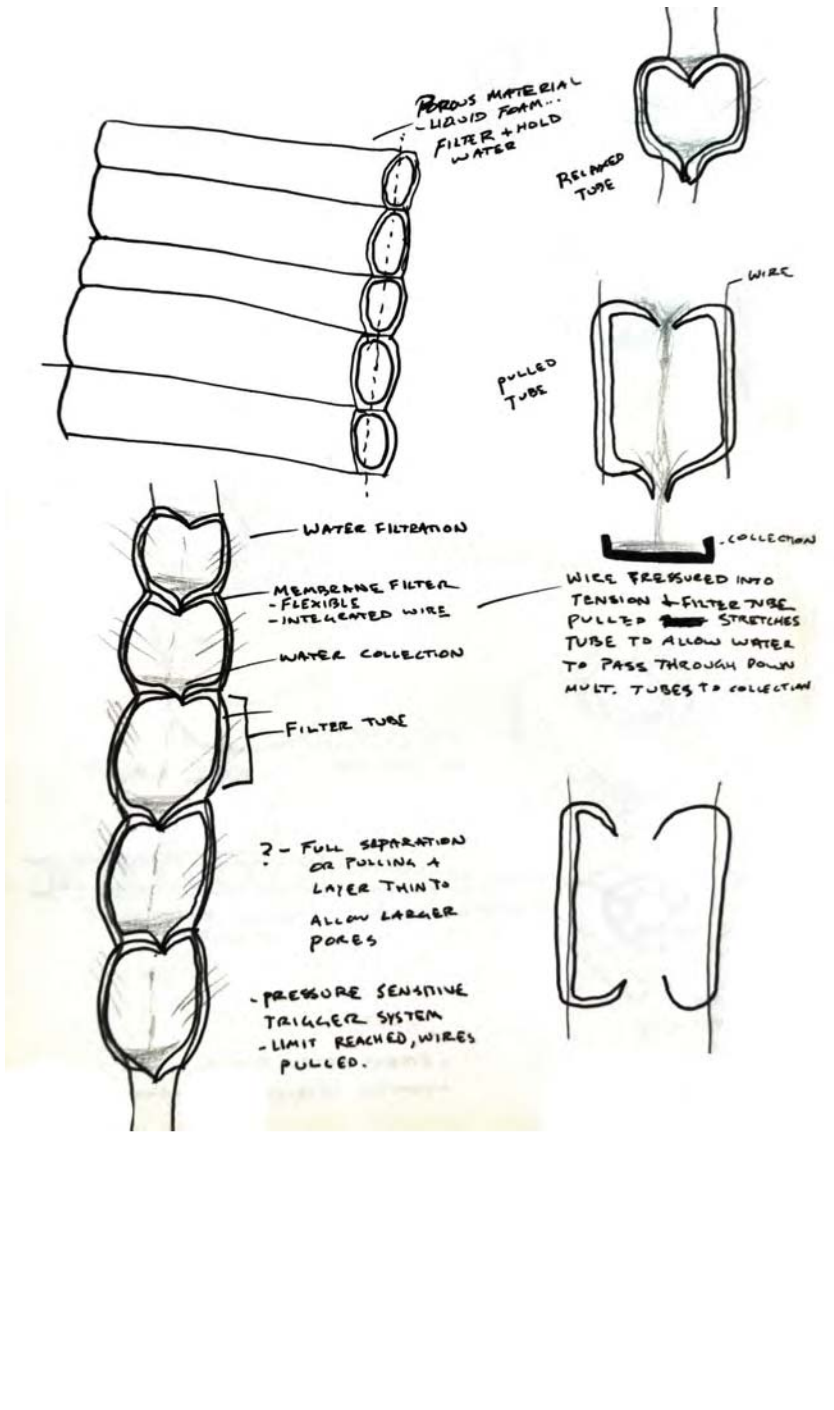
- Building skins that are bio-reactive. Surfaces that respond to changes in ambient temperature or touch due to increasing crowds. Perhaps occupancy sensors or heat detectors cause certain areas of the building to react to large crowds. These responses could include changes in color, texture, opacity and/or luminosity.

- Shading systems that react to the sun as it travels across the building façade. Two avenues could be explored:

    1. Glazing that has an inner or middle layer that changes opacity in response to changes in sunlight levels.

    2. A shading device (internal or external) that mechanically shifts in response to the sunlight. This shifting could cause pattern alignments that block out the sun's rays or that cause an "unfolding" of a membrane which retracts as the sunlight recedes.

- A building with a multi-layer skin membrane – perhaps like a tensile structure. The outer skin could be a flexible membrane supported by a system of tension and compression. Various portions could be designed to respond to various external stimuli and/or act in unison. Inhabitants can interact with the built environment and see how changes in the environment are mirrored by detectable changes in the building. Perhaps it reshapes or reforms itself. Or the windows change color depending on the weather outside. There are endless possibilities.


POROUS MATERIAL
- LIQUID FOAM...
FILTER + HOLD WATER
RELAXED TUBE
WIRE
PULLED TUBE
COLLECTION
WATER FILTRATION
MEMBRANE FILTER
- FLEXIBLE
- INTEGRATED WIRE
WATER COLLECTION
FILTER TUBE
WIRE PRESSURED INTO TENSION + FILTER TUBE PULLED STRETCHES TUBE TO ALLOW WATER TO PASS THROUGH DOWN MULT. TUBES TO COLLECTION
? - FULL SEPARATION OR PULLING A LAYER THIN TO ALLOW LARGER PORES
- PRESSURE SENSITIVE TRIGGER SYSTEM
- LIMIT REACHED, WIRES PULLED.

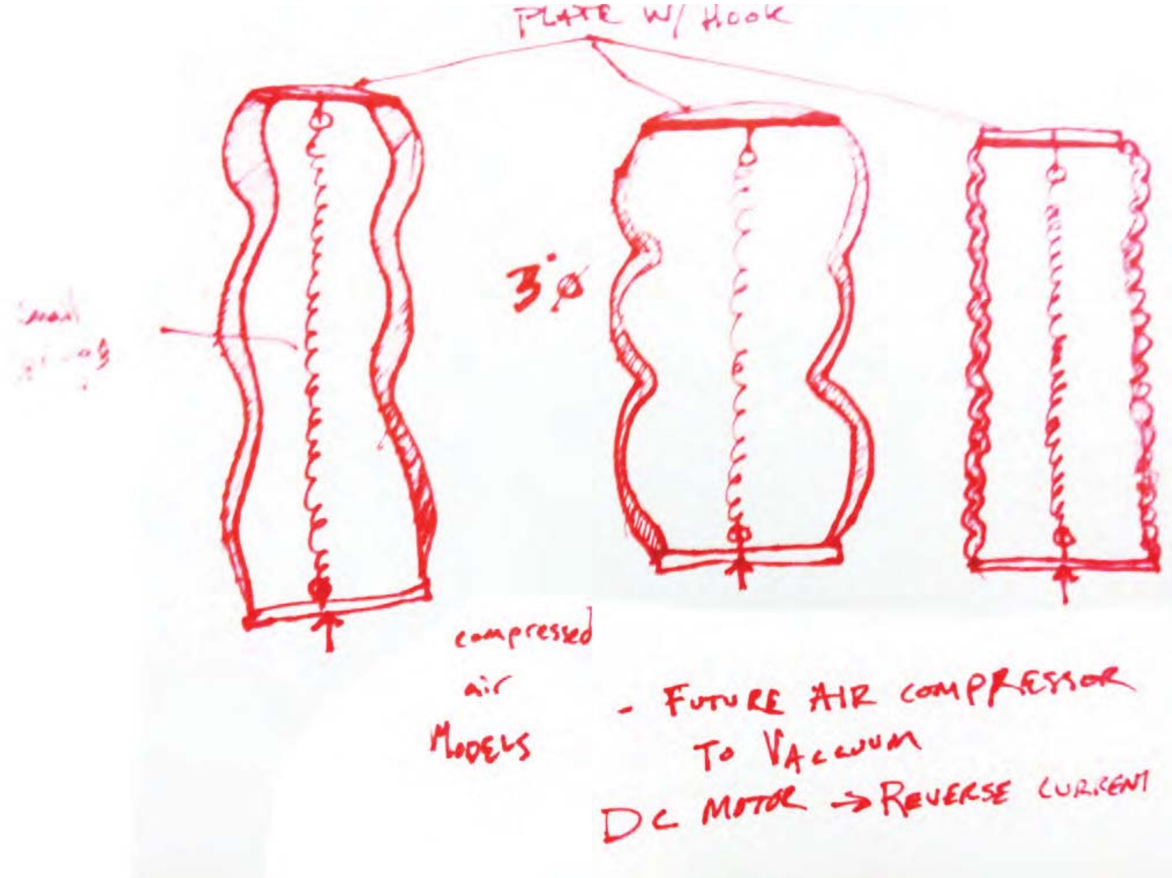
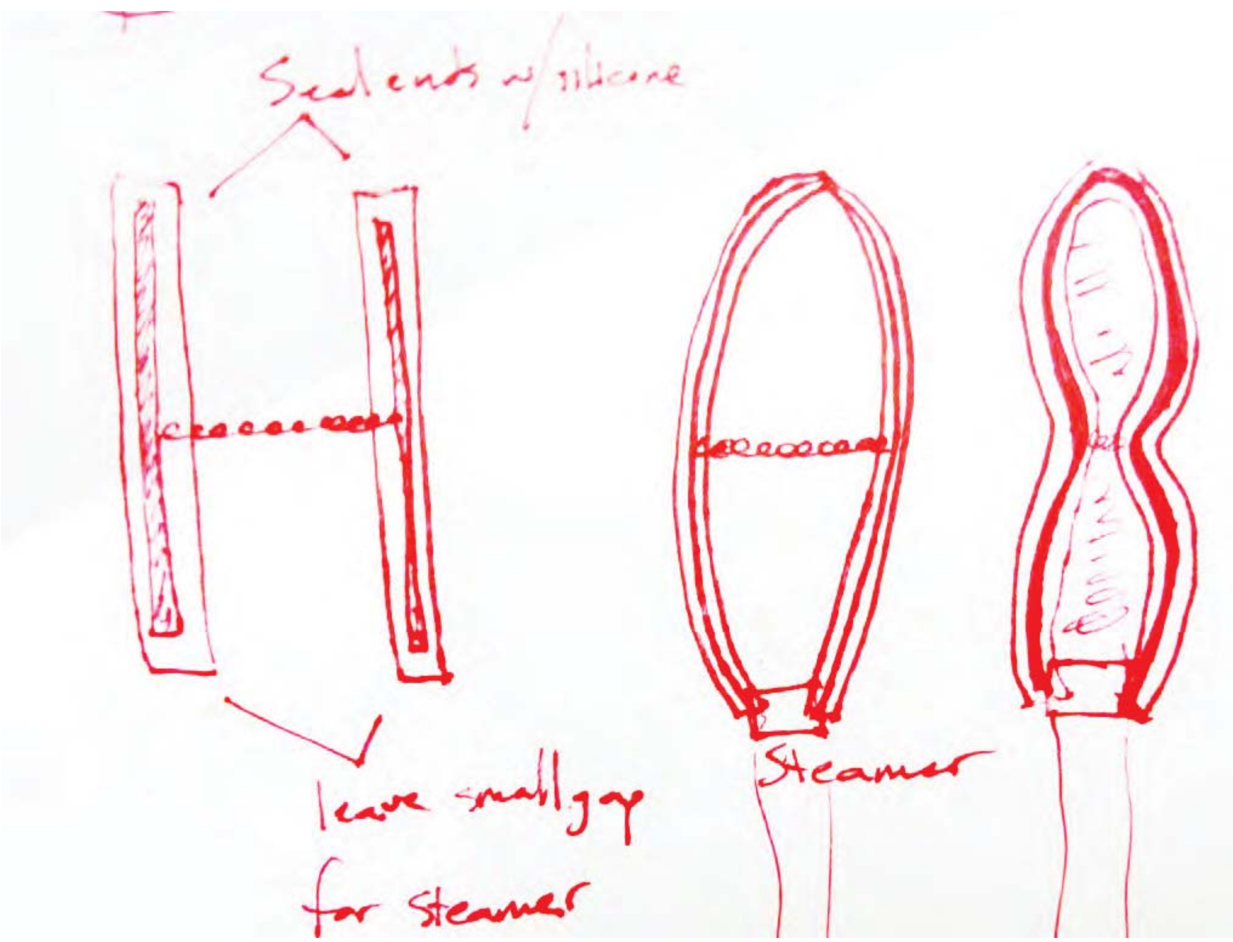


PLATE W/ HOOK
3" ø
compressed
air
MODELS
- FUTURE AIR COMPRESSOR
TO VACUUM
DC MOTOR → REVERSE CURRENT


Seal ends w/ silicone
leave small gap
for Steamer
Steamer

3 MODEL 1

EXPANSION/CONTRACTION

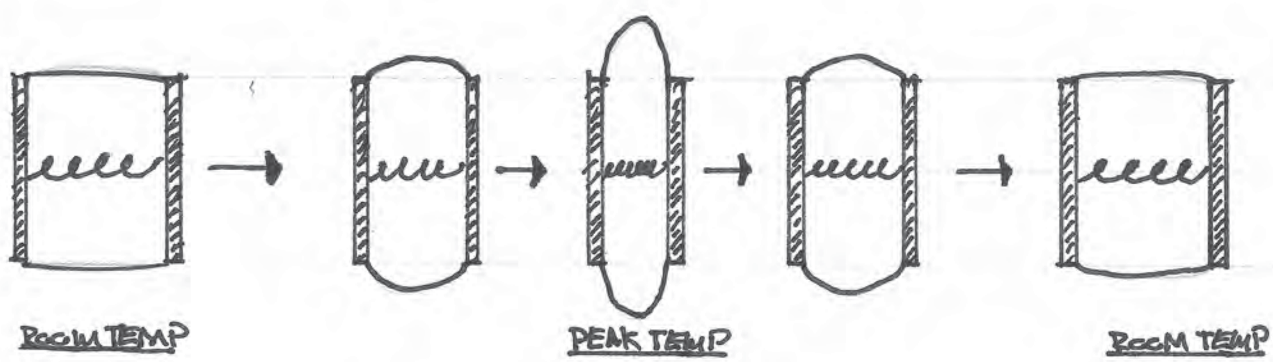
This model explores the activities of the organism's body wall during expansion and contraction. Three separate phenomena will be explored. First the model will explore the mesenterial retractor muscles; these muscles constrict causing the release of the internal water pressure within the body wall. This epilation of pressure causes the body wall to compress reducing its thickness and increasing its translucency which is the second focus of this model. Lastly, the model will explore the use of water pressure to reset the body wall to its maximum thickness.

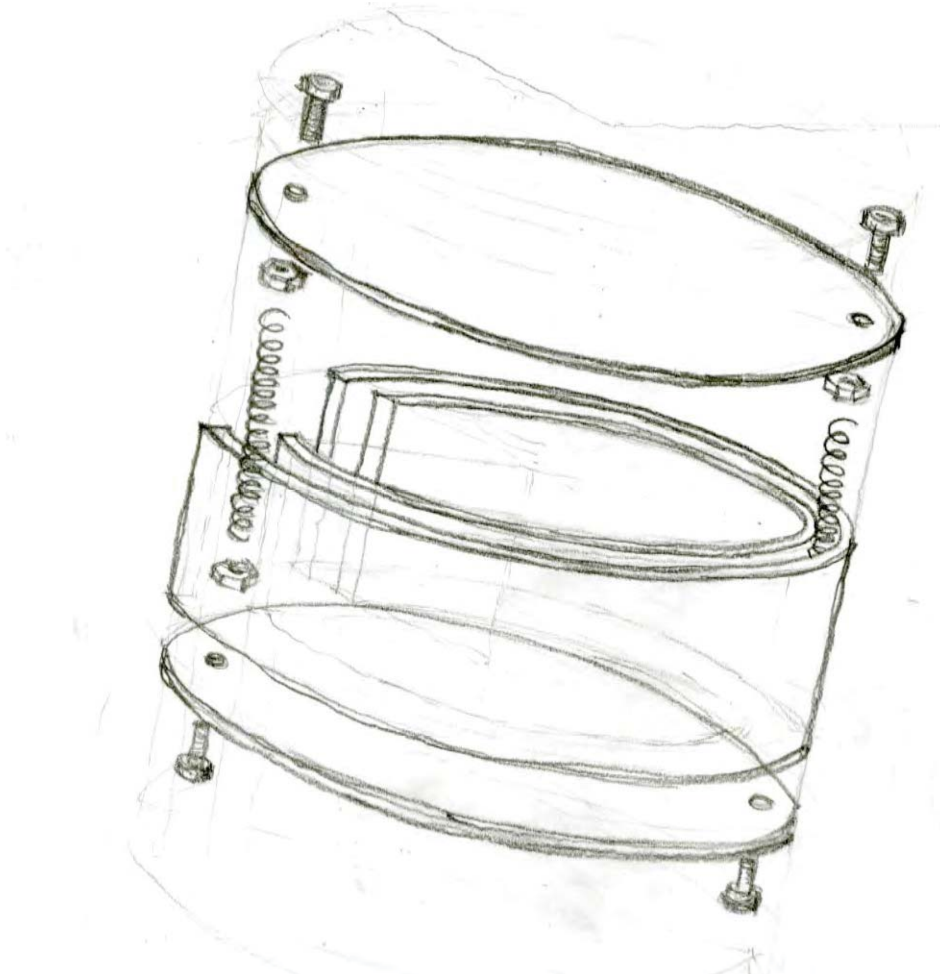
Exploring the movement of the retractor muscles involves placing helical nitiinol wires between two acrylic planes representing the inner and outer body wall. The acrylic planes will be cut to the desired shape using a 3-axis C & C Machine, the inspiration for using the C & C Machine is derived from similar equipment used at Quality Metal Craft. As the helical wire is heated it will contract pulling the acrylic planes closer together.

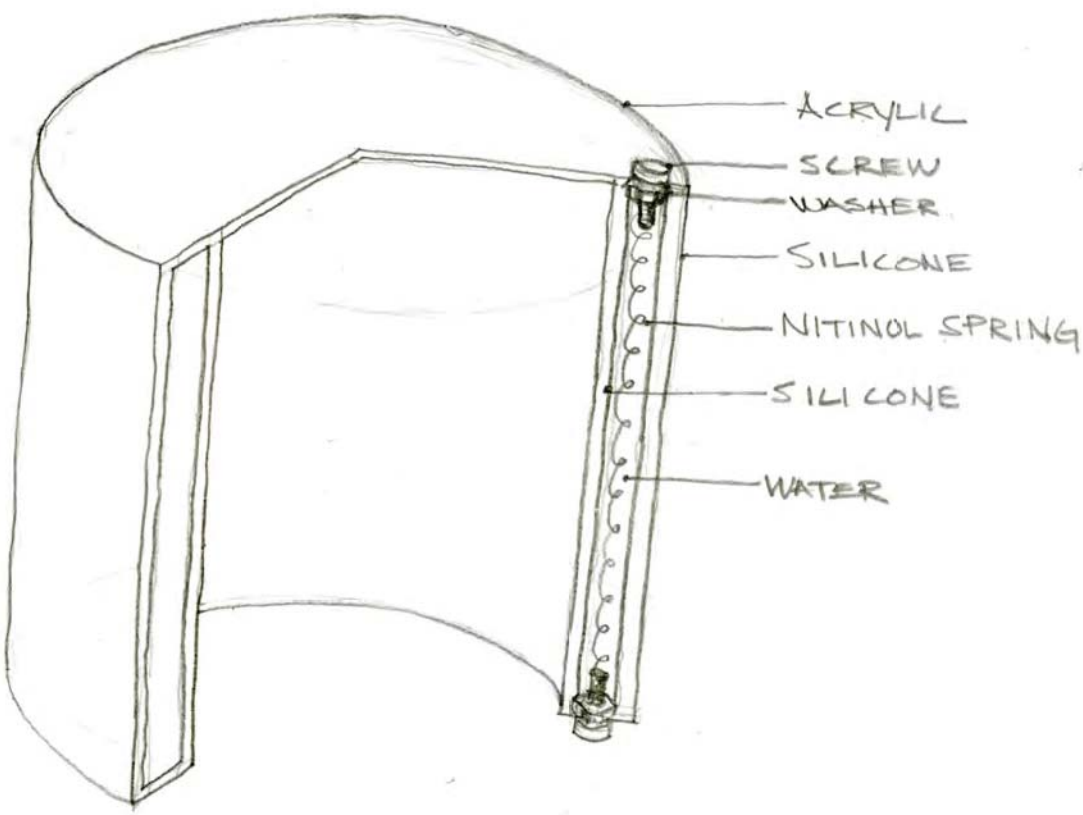
The planes and wire will be surrounded by a silicone sleeve which will be cast in a form, much the same way Ransom and Randolph and Quality Metal Craft use casts to form jewelry and dies respectively. The silicone is flexible to allow for the movement of the acrylic planes. The air now enclosed by the silicone sleeve and acrylic planes will be replaced with fluid. Once heated the acrylic planes will begin to move closer increasing the fluid pressure inside. Once the helical wire has cooled the internal pressure will cause the planes to reset back to their original starting points.

Lastly, as the acrylic planes move closer the translucency of the fluid will increase, similar to the reaction of the anemones skin when the internal fluid is released. As the helical wire cools and the shape resets, the opacity of the fluid will increase.

Through experimentation this model will allow us to explore the properties of many materials and fabrication processes and gain a better understanding of the actions of the anemone during the process of expansion and contraction.






ACRYLIC
SCREW
WASHER
SILICONE
NITINOL SPRING
SILICONE
WATER

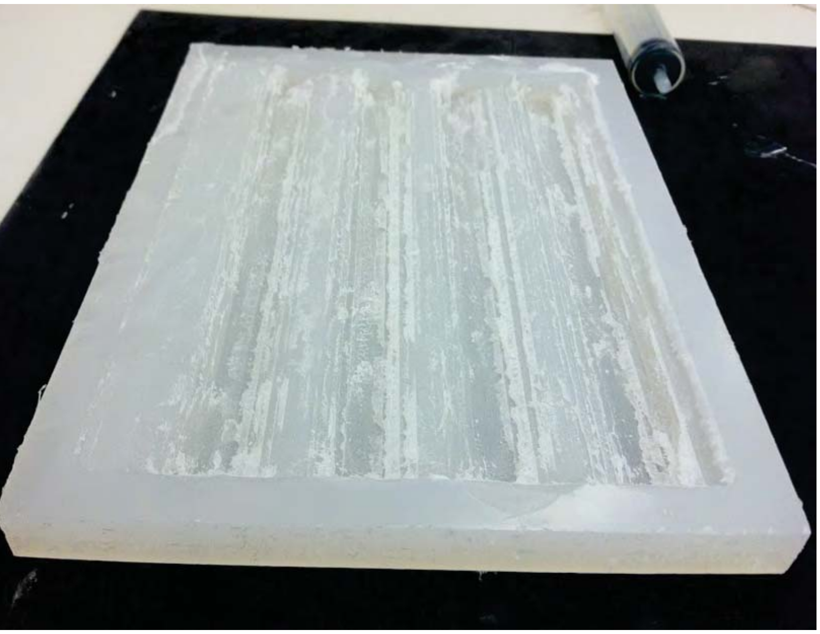
Quality Metal Craft

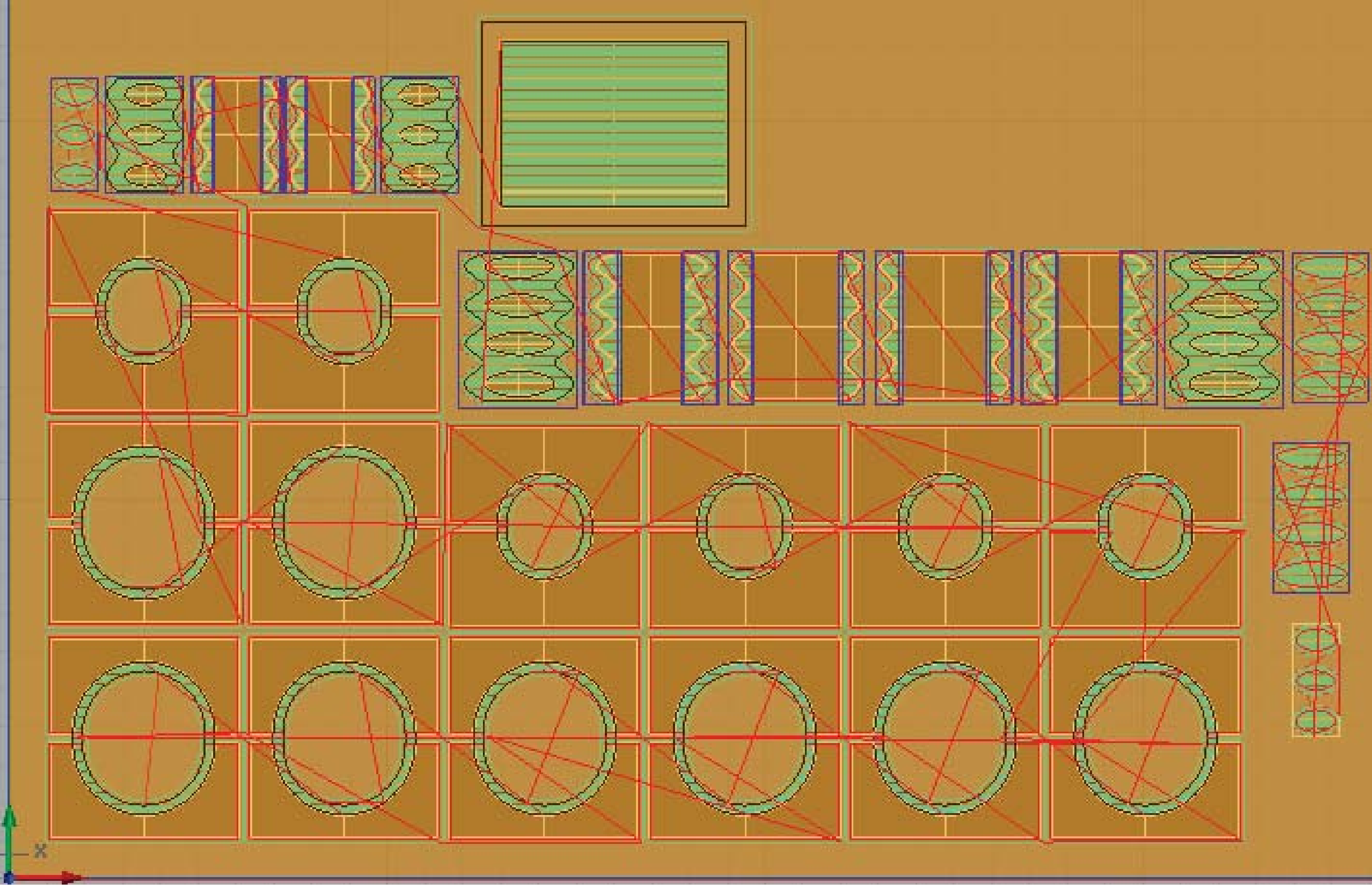
Ransom & Randolph Casting Equipment

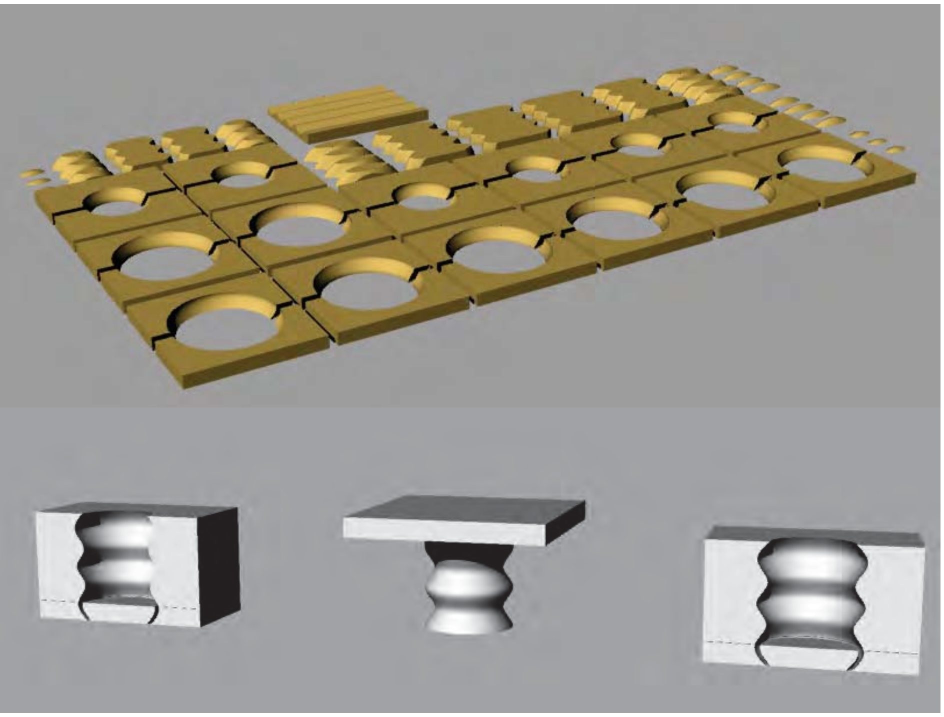
Team casting silicone moulds

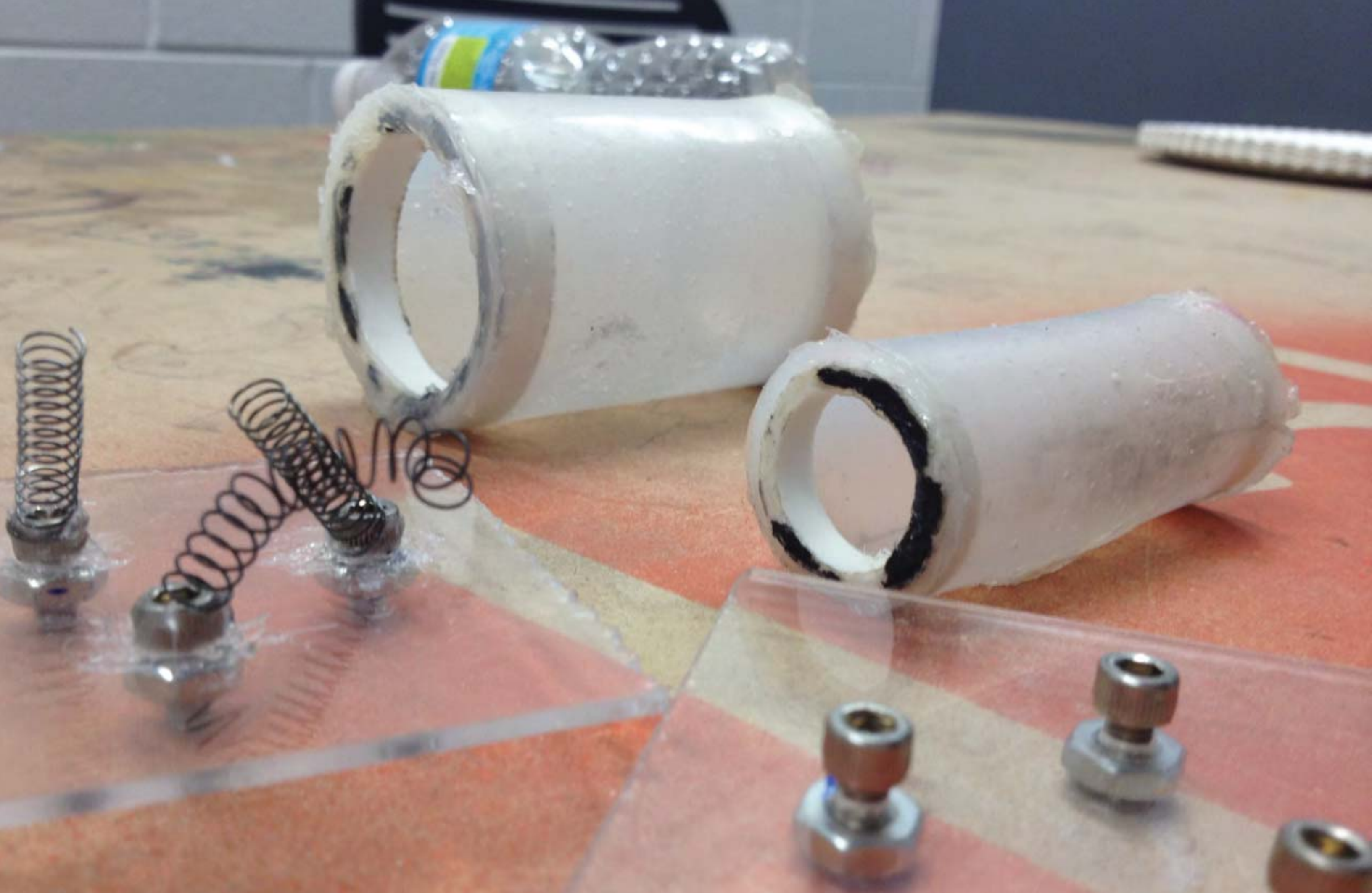
Left page: Silicone
casting techniques

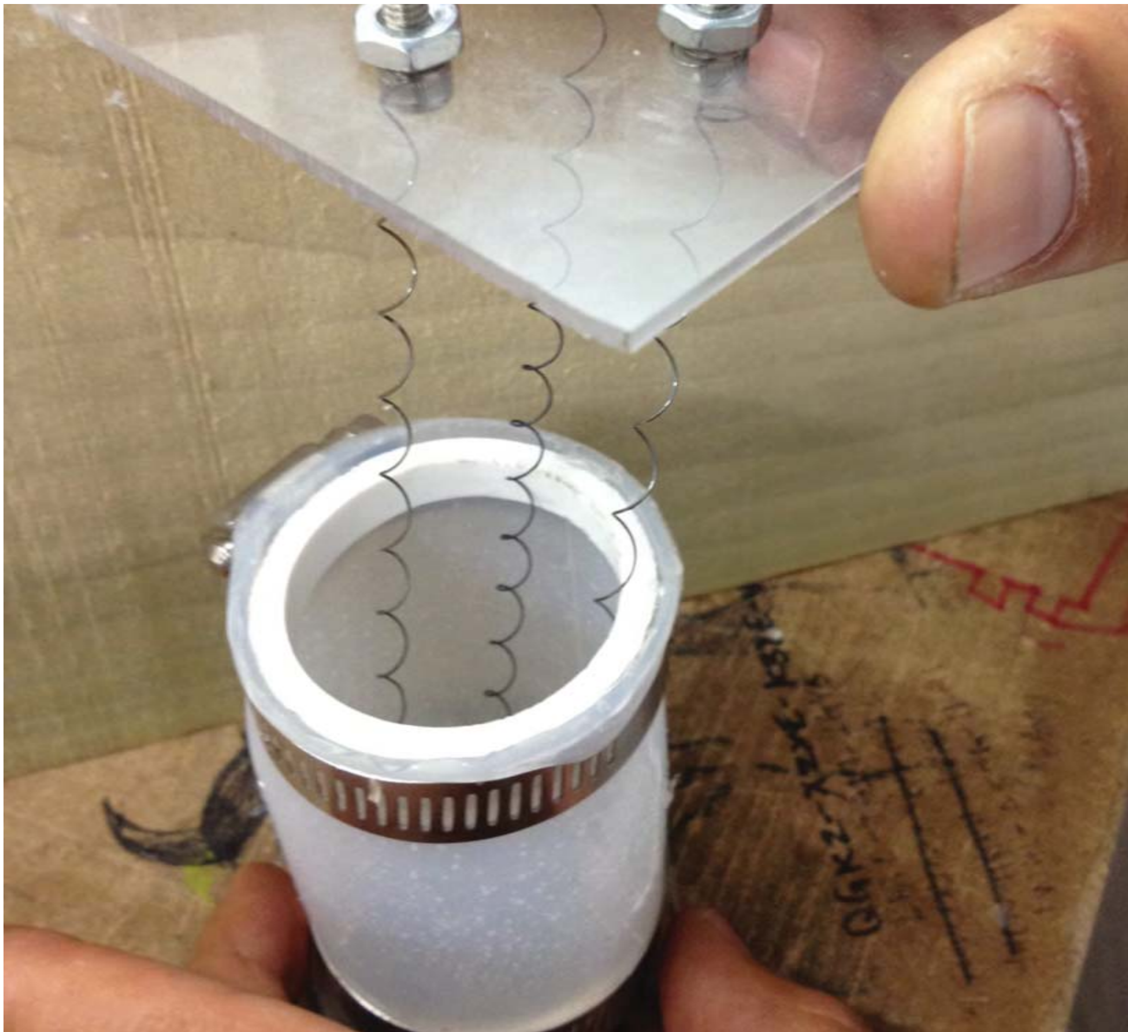
Right Page: CAD generated
laser cutting patterns





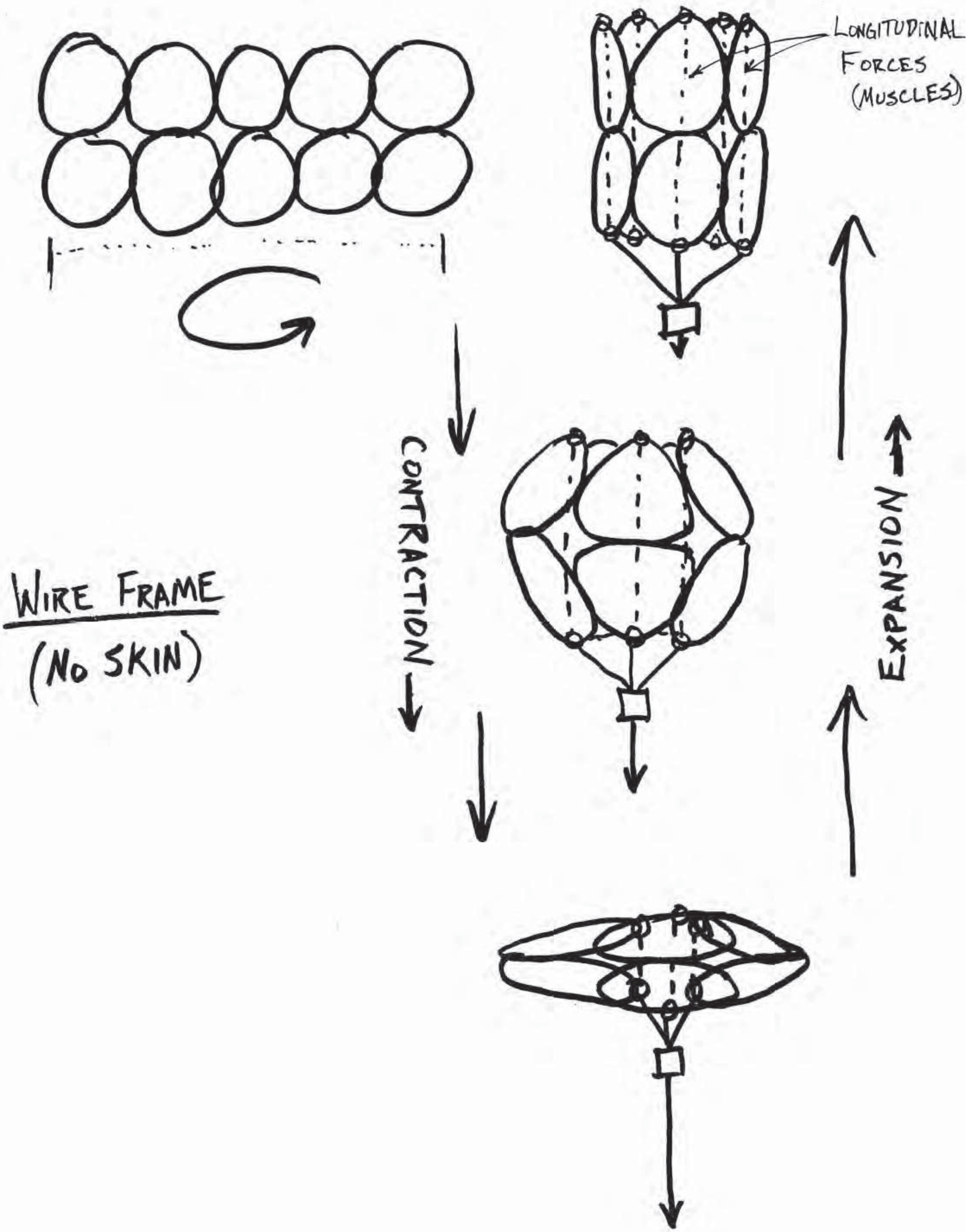






left page:
construction
process of model

right page:
complete model


LONGITUDINAL FORCES (MUSCLES)
CONTRACTION
EXPANSION
WIRE FRAME
(NO SKIN)

4

MODEL 2

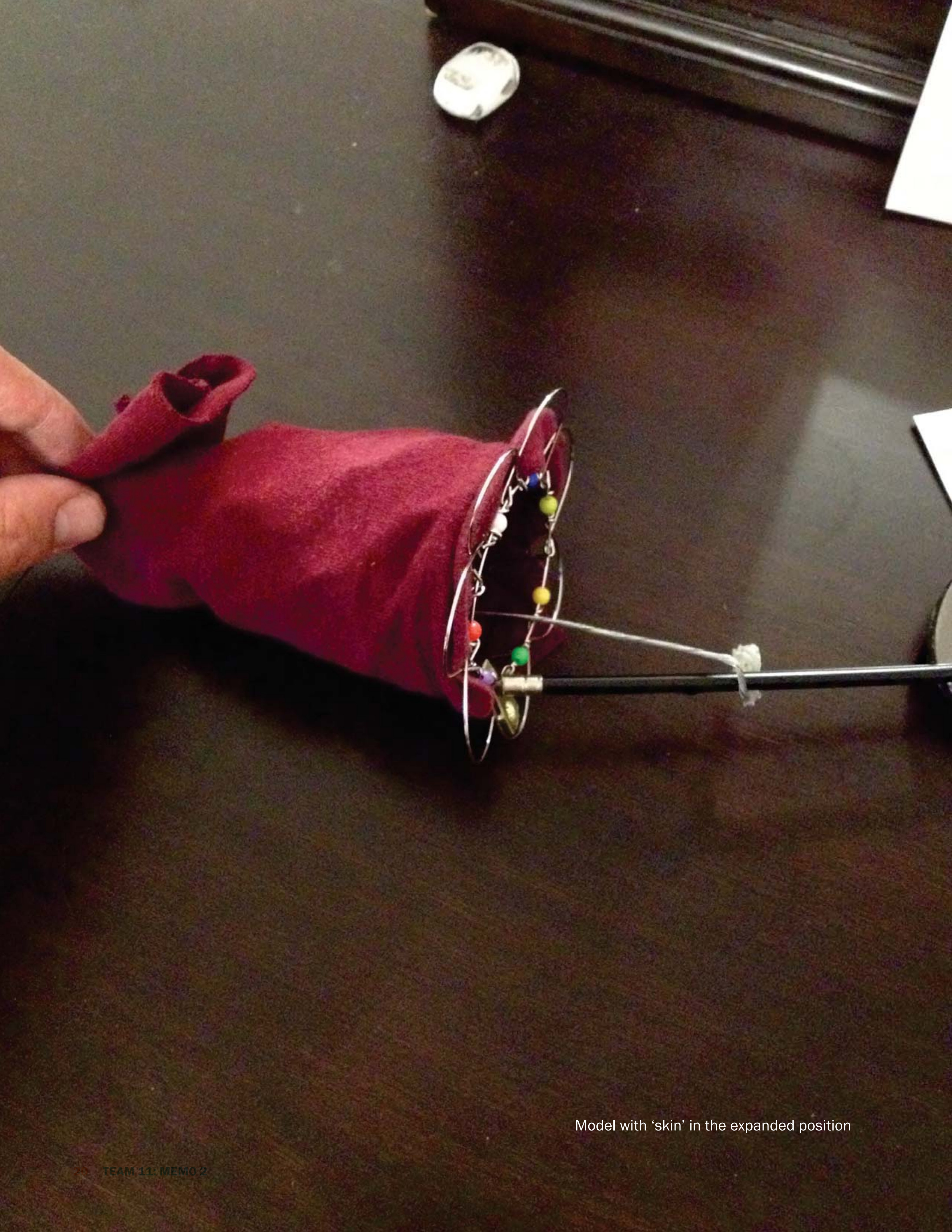
EXPANSION/CONTRACTION

In general, the model depicts the process of expansion and contraction of the organism. The tube anemone contracts sharply when sensing danger by using longitudinal muscles to pull downward and release the stored water through the back of the tube. This allows the body to compress. The expansion is a much longer process. The organism must replenish its membrane with water, which usually takes days.

In this model, the break wire that is connected to the top and bottom of the frame represents the longitudinal muscles that cause the organism to contract rapidly. The body of the tube is made up of a series of connected wire rings that move in synchronization with each other. The skin is a flexible cotton/spandex material that conforms to the shape of the tube in all positions. Direct coordination of the materials working with and against each other to create simultaneous movement is comparable to the stamp press used at Quality Metal Craft. Once metal is stamped into a mold at QMC it has a tendency to slightly return back to its original position or shape. With this model the cotton/spandex material can be held in resistance or freely allowed to return back to its orignal form; returning the action of the model back to its original position.

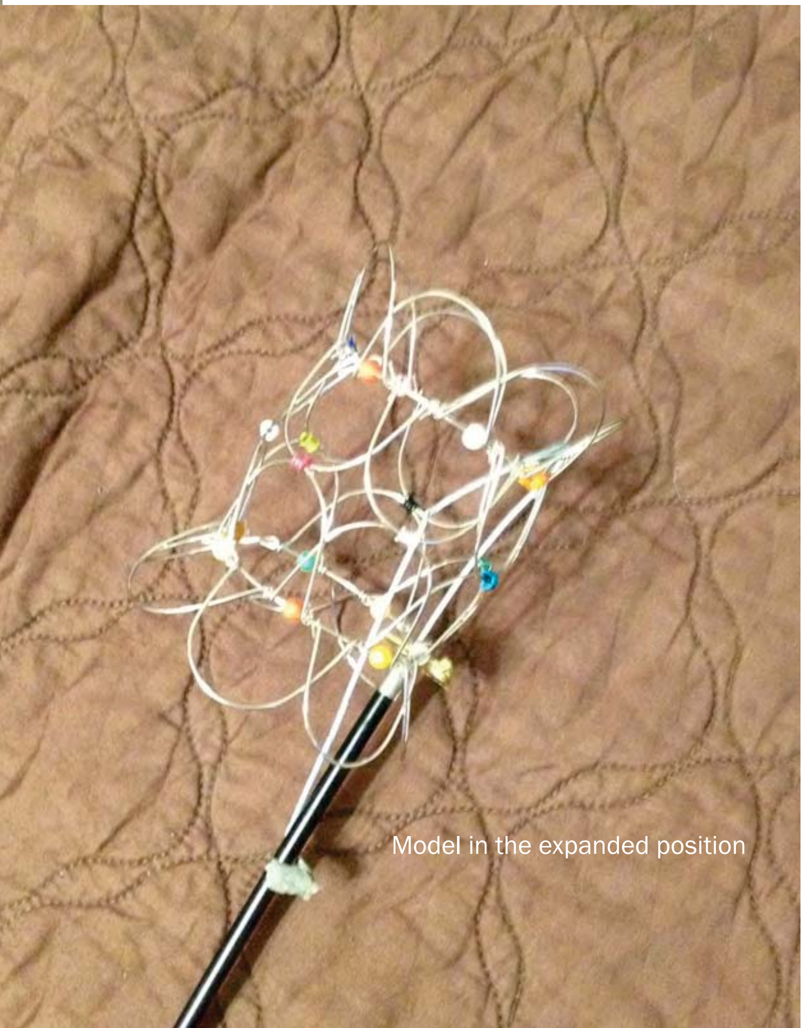
As the break force is applied, the tube model contracts, flattening almost completely. The longitudinal forces contract and cause the width around the middle of the tube to expand; thus, accommodating more density in smaller space. Once settled, the expanded center of the tube then starts the slow process of returning back to erected form by means of soft springs and bands that pull back together.

There is much more to gain from this model by studying the detail in which each portion of the body moves. The cause and reaction is more than simply a domino effect—it is instantaneous. One portion of the body cannot move without another. All parts work together as one.



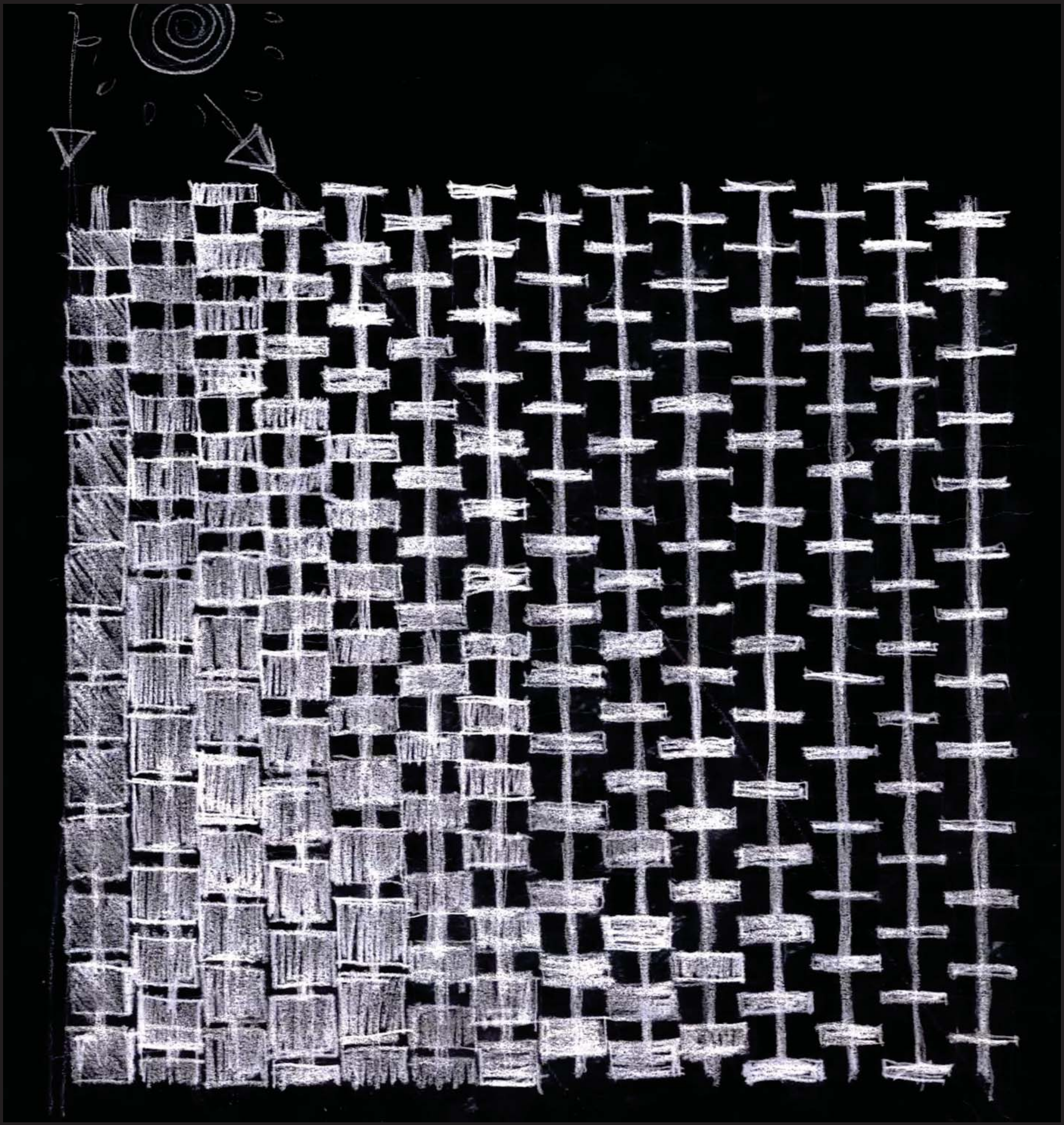
Model with 'skin' in the expanded position

Stamp pressing of metal at Quality Metal Works



Model in the expanded position

Model in the contracted position



5 MODEL 3 (WORK IN PROGRESS)

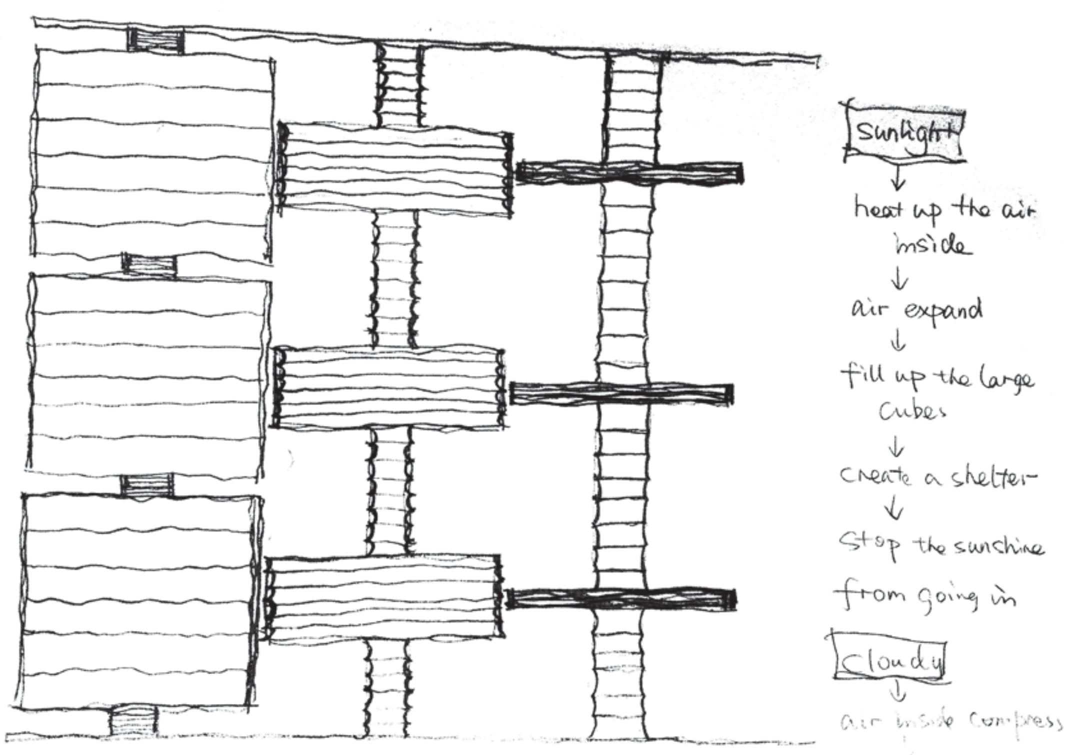
EXPANSION/CONTRACTION

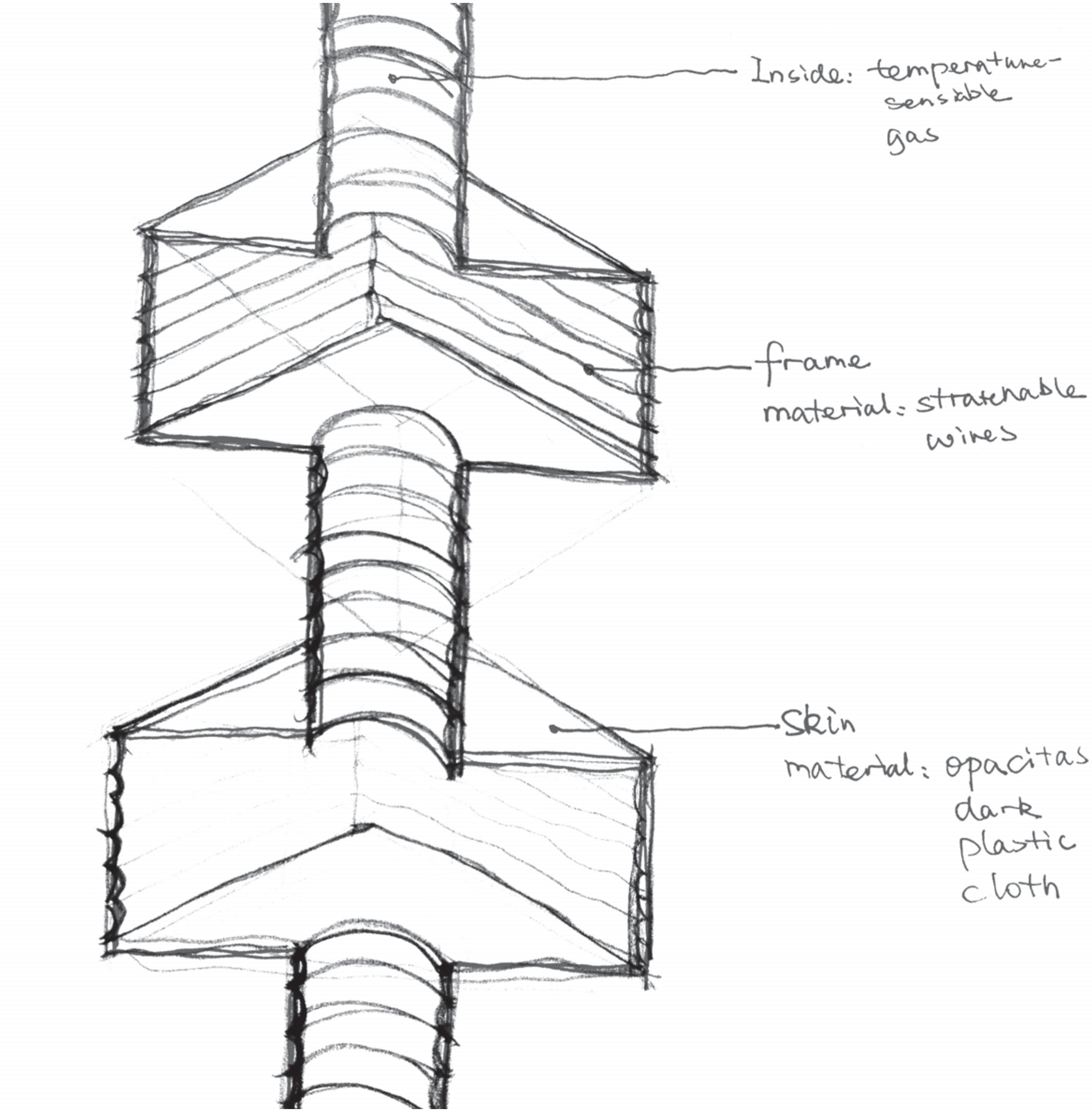
Contraction and expansion is the most characteristic behavior that the tube anemone does according to the changes of the surrounding environment. And it is the most important one. Our model here is design to demonstrate this very responsive organism, and develop the system material-vise exploring the possibility future use.

The main part of the model consists of two thin square boards placed paralleling each other. Their four corners are connected with four springs to form up the frame of a cube. This cube is covered up with super stretchable plastic. These two boards each has a hole in the middle which connected to a tube made of temperature-sensitive material. Both the other ends of the two tubes are fixed and cannot move. (This model is not final yet, if we cannot find this tube material in the end, we will go with the hole in the middle of the board is connected to an air compressor. It will be given a certain pressure and keeps working till the tube is filled up. The sensor senses the pressure and stop pumping the air in. The thin material of the cube wall let the air out slowly and the box gradually flats up and the air compressor starts working again").

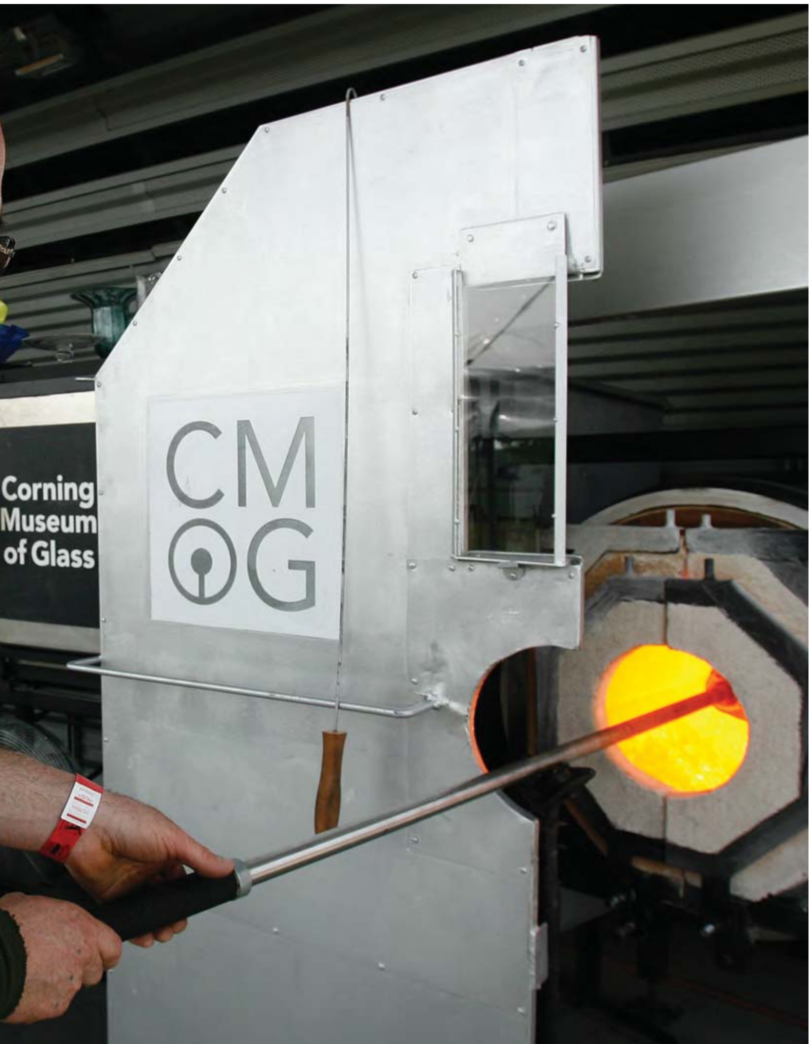
Through the tour last weekend to the glass pavilion, we learned that there are two different kinds of fire: practical fire and phenomenal fire. Practical fire is used in a basic sense - to heat, provide light, and etc. Phenomenal fire creates an experience with the user - it goes beyond the necessities and is used to continue, start, or stop another process - or to do something else. In this point, the sun can be recognized as both. It is practical fire for it offers heat, and it is also phenomenal fire because it activates our model. The device operates when the sunlight changes its track. When the sun shines directly on the model, the tubes warm up and expand, they compress the cube in the middle and press it flat; then the sun goes away, the device cools down the tube contracts and the springs inside push up the box.

In this case, this device can create a shade when sunshine is fierce and close down when the sun goes away. So it is possible to carry this further to form up a system. A great deal of tubes and cubes connected to each other forming up a second building skin over the glass wall and act as a spontaneous organism to protect the architecture form excessive sunlight.




Inside: temperature-
sensible
gas
frame
material: stretchable
wires
Skin
material: opacitas
dark
plastic
cloth

Glass Pavilion



Glass Pavilion Oven

6 CONCLUSION

Expansion and contraction is essential to the survival of the tube anemone in two ways. First (at the macro-level), it allows the anemone to respond to immediate danger by enabling it to retract into its protective tube, concealing its soft body from many predators (and from light). The second use of expansion and contraction (at the micro-level) is during the regenerative process and as a way to maintain equilibrium of if its cylindrical form.

During the course of research it was noted that the expansion and contraction of tube anemone is not only due to its longitudinal retractor muscles, but also to the hydrostatic pressure which builds up within the anemone when it is fully distended, and is later released when the anemone contracts into its tube. This concept of hydrostatic pressure is interwoven with the tube anemone's entire pattern of life and is vital, not only in expansion and contraction, but also in growth, regeneration, and form regulation.

The molding, shaping, forming and fabricating techniques observed during the tours opened up new methods of model design and exploration. We were able to experiment with variations in molds, changing the density, proportions, shapes and sizes of multiple-layered membranes to determine which combinations produced the best results. We were able to experiment with a variety of actuators to see how mechanical action can be initiated from non-mechanical stimuli. We also were able to combine processes to see how one process affected another, altering the nature of the initial theory.

One avenue that proved promising was embedding actuating materials into responsive materials in the mold. By doing this, instead of having a clear distinction between the cause and the effect, there is a melding of the cause and the effect. The cause becomes the effect. The nature of the material itself is transformed and a new material is created which responds differently to its environment. The new material now has to ability to react to an external stimulus and reset itself. This new material can then be applied in more "traditional" building technologies to transform the way we design and shape our built environment.

The creation of new materials by means of mass-production methods provides exciting prospects that open up additional possibilities for application of the modular unit designs on a larger scale. These unit designs can then be applied to system designs that can create architectural phenomena – interactive experiences that allow the users of spaces and places to do more than just look at their surroundings. This is where the dividing line between spatial and structural or practical and phenomenal is crossed. It is the goal of Team 11 to further blur this distinction and blend the world we actually experience with the world we can conceive.

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