Immunodrop

Design Matrix

Design Matrix

BME 200/300 Section 312
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Client

Dr. Cristina Sanchez de Diego

Advisor

Dr. Monica Ohnsorg

Team

Sam Kamin sjkamin@wisc.edu (Co-Team Leader)

Murphy Diggins mdiggins@wisc.edu (Co-Team Leader)

Dylan Libel libel@wisc.edu (BWIG)

Vir Jaiswal vajaiswal@wisc.edu (BPAG)

Will McGuire mjmcguire@wiisc.edu (BSAC)

Eduardo Usandivaras usandivaras@wisc.edu (Communicator)

Microfluidic Mold Designs

Design 1 (Thin No Outlet): This mold has one inlet and one outlet, with no dedicated ports for biopsy punching. Its 75 µm constriction was designed to produce droplets approximately 100–200 µm in diameter, although the final size will depend on channel height and flow rates. A retaining wall contains the PDMS during casting. The turns lengthen the collagen flow path and add resistance, helping control its flow into the droplet-forming junction.

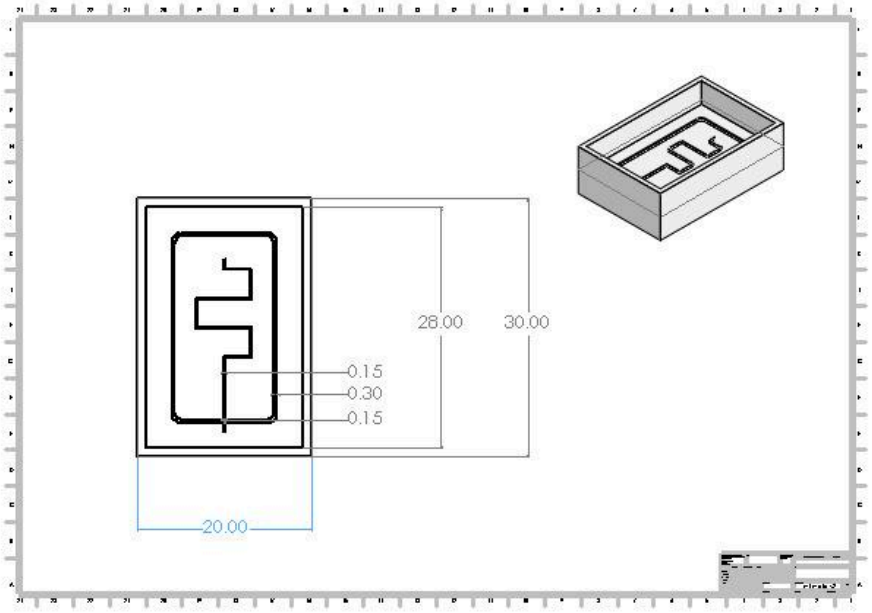


Figure 1: Thin No Outlet Design

Design 2 (Smooth Design): This design uses 750 µm collagen channels and 1,000 µm oil channels, with the goal of producing approximately 0.5 µL volume droplets. Compared with Design 1, its smoother turns provide a more gradual flow path, while dedicated inlet and outlet ports make the device easier to connect and fabricate. The shorter retaining wall also reduces the amount of PDMS needed for each mold.

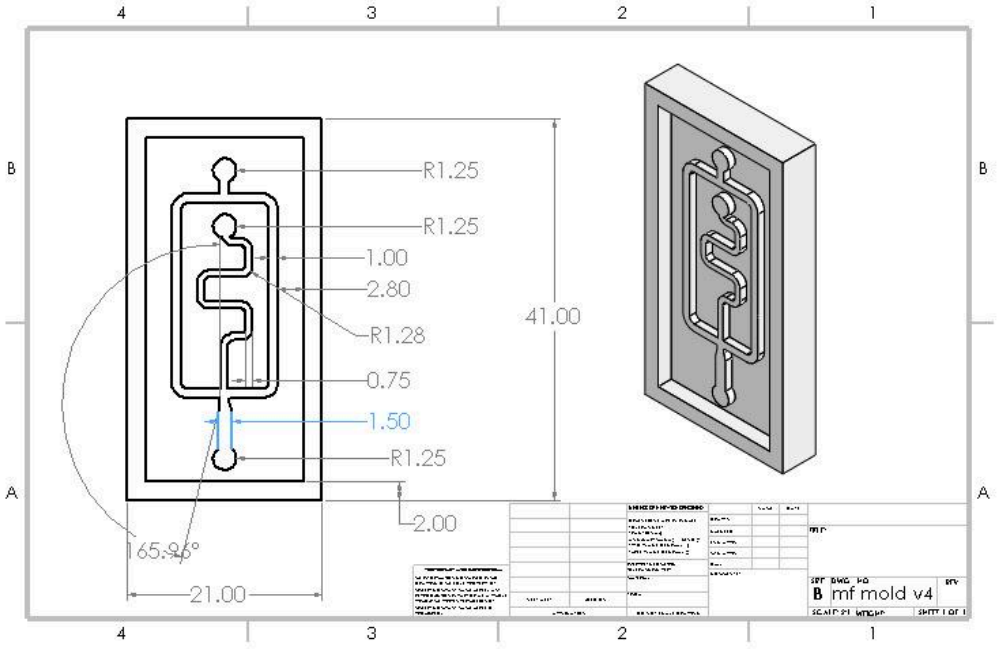


Figure 2: Single Outlet Design

Design 3 (4-Outlet Design): A scaled-up version of Design 2, this design places four separate droplet generators on one chip to increase the number of droplets produced at once. It keeps similar channel dimensions and port sizes, with the collagen and oil routed to each generator. The smooth turns are intended to keep flow consistent, while the shared chip and retaining wall make it possible to cast all four generators in one PDMS mold. Flow will need to be tested to see whether all four generators produce droplets at similar rates.

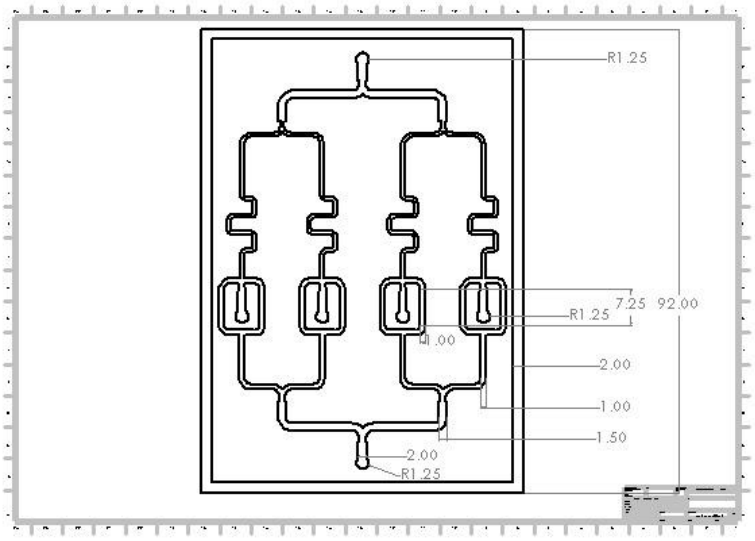
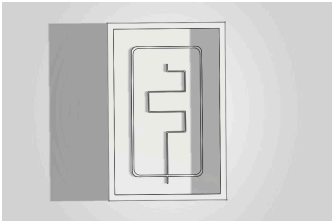
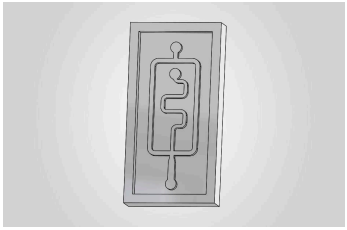
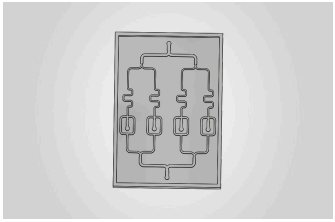


Figure 3: Four-Outlet Design

Matrix 1: Microfluidic Mold

Criteria (Weight)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Design Sketch	Design 1: Thin No Outlet 		Design 2: Smooth Design 		Design 3: 4-Outlet Design 	
Flow (25)	3/5	15	4/5	20	5/5	25
Accuracy (20)	3/5	12	4/5	16	4/5	16
Usability (20)	3/5	12	4/5	16	4/5	16
Throughput (15)	2/5	6	4/5	12	5/5	15
Reliability (15)	5/5	15	4/5	12	3/5	9
Ease of Fabrication (5)	3/5	3	4/5	5	4/5	4
Total (100)	63		81		85	

Criteria Description and Rating Rationale

Criteria 1 - Flow:
Flow is a critical criterion in the ranking of the microfluidic molds because the flow must be controlled to yield the ideal size droplets at the ideal rate of droplet generation. The designs are ranked based on the ease of controlling the flow rate and the predicted outcome from the variability in channel size and turns.

- Thin No Outlet: Being the mold with the smallest channel width (75µm), the flow for this device must be more precise since droplet size is set mostly by geometry and flow-rate ratio rather than the absolute flow rate itself. This is advantageous for reproducibility but can cause high shear rates with cells passing through. The sharp turns add resistance intentionally to tune flow into the junction, but may create uneven velocity at each corner. Furthermore, no dedicated Biopsy ports lead to more variability for tubing connection, which can cause leaks or bubbles unrelated to the channel design.

- Smooth Design: With dimensions of 750/1000 μm, channels are effectively larger with a much lower flow resistance, which will require higher flow rates to get meaningful shear at the T-junction. This could make the droplets more sensitive to flow. The smooth turns give the mold more uniform flow into the junction than the previous design. Additionally, the ports significantly improve connection repeatability, so the flow rate set is more likely to be the flow rate delivered.
- 4-Outlet Design: Each individual droplet generator should behave much like Design 2 in isolation, since the dimensions are unchanged. However, flow distribution across the four parallel generators must be considered. Slight differences in channel length, PDMS height, or partial clogging in one T-junction can shift flow rates unevenly. This must be tested rather than assumed.

Criteria 2 - Accuracy:
Accuracy is a major part of the project, as it dictates the droplet size produced by the microfluidic droplet generator. For this device, a deviation from the 0.5 μL droplet size is allowed but discouraged. An increase in the size of the drops may cause them to be too big to fit through the body's canals, and smaller drops may not contain enough B and T cells. With these limits in mind, the ranking for accuracy in the design matrix became the second largest. Controlling and having a steady size of collagen droplets is paramount to the success of the droplet generator.

- Thin No Outlet: The “Thin No Outlet” design was tied for the lowest score within the accuracy criteria. This is mainly due to the thinner and more jagged channels the collagen is pumped through. With less room to flow and sharper turns, the collagen can easily get clogged within the mold itself or flow through the opening at an irregular rate due to fluid mechanics and overlap. Therefore, this mold is more likely to produce irregular, less accurate droplet sizes, giving the design a 3/5 in accuracy weighting.
- Smooth Design: The “Smooth Design” is able to get accurate and consistent droplet sizes, giving it a 4/5 score. This design attempts to improve on the “Thin No Outlet” design by using low-friction channels, with walls that are much more conducive to collagen flow. The wider channels also attempt to reduce the likelihood of blockage, giving the mold geometry less chance to affect droplet size.
- 4-Outlet Design: With this mold, many of the same implementations as the “Smooth Design” are used. For the “4-Outlet Design,” the increased number of channels and outlets can increase the chance for blockages or clogs to form within the channels. The channels in this design are modeled off the “Smooth Design,” which will help the flow of collagen and oil through the mold, but the larger surface area will lead to a higher output of correctly sized beads.

Criteria 3 - Usability:
The ultimate goal of the project is to create a functioning device for Dr. Sanchez de Diego. Keeping that in mind, the usability of all components in the project is a key criterion for consideration. The microfluidic chip designs are ranked based on their projected ease of use in simplifying Dr. Sanchez de Diego's workflow.

- Thin No Outlet: The first design ranks the lowest in usability, scoring a 3 out of 5, due to the lack of dedicated circular port holes on the chip. This means that Dr. Sanchez de Diego would need to use a biopsy punch to create ports for syringe tubing to enter at a random location. Due to the additional step and uncertainty in port placement, this design ranks lowest.
- Smooth Design: The smooth design excels over the no outlet design because it has ports and outlets. This simplifies the process of inserting syringe tubing and collecting the droplets once they are formed. Additionally, the wider channels make this design more usable, as it allows larger droplets to encapsulate the amount of B and T cells Dr. Sanchez de Diego desires. Therefore, this design scores a 4 out of 5 in usability. It is not a perfect score because feedback from the client is needed to get a perfect score in usability.
- 4-Outlet Design: The 4-Outlet design provides the same usability benefits as described above with the smooth design; the only difference is that the design is repeated four times to allow for a higher droplet generation rate. This increases the usability as it drastically reduces the time for droplet processing; however, the usability may also be reduced as the increased number of channels introduces a greater chance for clogging or variation in droplet sizes. Thus, this design scores a 4 out of 5 in usability as well.

Criteria 4 - Throughput:
The throughput is a measurement of the number of microbeads produced per unit time. Throughput is one of the specific requirements from Dr. Sanchez de Diego and is thus a necessary criterion to evaluate the microfluidic chip designs against. Dr. Sanchez de Diego requires the device to produce at least 300 collagen beads but, more effectively, closer to 600 collagen beads during each cycle.

- Thin No Outlet: The first design provides a simple microfluidic chip layout. The throughput can be changed by manipulating the flow rate of the oil and collagen. The lack of circular ports to be biopsy-punched makes this design score low, as it is susceptible to leaking. This can harm the total throughput of the microfluidic device. This design scores a 2 out of 5 in throughput.
- Smooth Design: The smooth design vastly improves upon the previous design in terms of throughput. The dedicated circular ports for biopsy punching prevent leaks and make tubing connections stronger. The more gradual flow path should contribute to a steadier, higher throughput throughout the device's operation. For these reasons, this design scores a 4 out of 5 in throughput.

- 4-Outlet Design: The 4-outlet design takes all the advantages of the smooth design and builds upon them. This design offers the same benefits in terms of dedicated ports and gradual flow while also multiplying the projected throughput by four. In terms of product specifications, this meets the throughput criteria the best and thus scores 5 out of 5.

Criteria 5 - Reliability:
The criteria of reliability mainly considers the effectiveness of each design over time and how each component will affect the output of each mold. More complexity within a design may lead to an increased number of variables and problems arising within the chip during use. The molding process for each chip may also become increasingly complex as the designs follow the same pattern, leading to an increased number of failed curings and molds that are unusable.

- Thin No Outlet: Because the constriction of the channel is small, droplet size tends to stay pretty consistent once the flow is running and the geometry does most of the work to keep the droplets uniform. Regardless, the lack of biopsy ports can cause shifts, leaks, or air bubbles to form between runs which can be harder to control
- Smooth Design: Here the droplets are more sensitive to small changes in flow, so it is likely that droplet size will vary, but that is acceptable to the client. That being said, the dedicated ports and smooth turn design makes the physical setup sturdier and easier to connect which allows for more repeatability and reliability for testing.
- 4-Outlet Design: The primary question for reliability for this design depends on test results to see if each channel behaves the same way as the smooth design. Small fabrication differences can cause the design to produce droplets at uneven rates or clog up, which would throw off consistency. Since there haven't been any tests with this device, it is fair to say that the 4-Outlet design carries the most uncertainty for reliability.

Criteria 6 - Ease of Fabrication:
Since all three designs use similar, relatively straightforward fabrication methods, ease of fabrication carries less weight in our design matrix. It is still worth considering, though, because we expect to make a new device for each use.

- Thin No Outlet: With its thinner channels and sharp features, this design is the most difficult to fabricate. The PDMS may tear when peeled from the mold, and the mold will need thorough post-processing to ensure the PDMS cures properly.
- Smooth Design**:** This design is straightforward to fabricate. Its wider channels provide more room for error and improve structural integrity during removal from the mold.
- 4-Outlet Design: This design is more complex than the others but should still be relatively easy to fabricate. Its additional channels create more places where the PDMS could tear during removal.

Cooling Mechanism Designs

Design 1 (Ice Cube Mold): This design aims to cool the collagen stream on the chip in three ways: vapor from the ice, direct contact with the ice, and meltwater flowing onto the chip. The mold has an 8° draft and will be printed in elastic resin to make the ice easier to remove. It will be filled to the brim so that the retaining wall lip forms a flat surface, allowing the ice block to sit flush with the glass. The cylindrical pillars create holes in the frozen ice for the tubing ports.

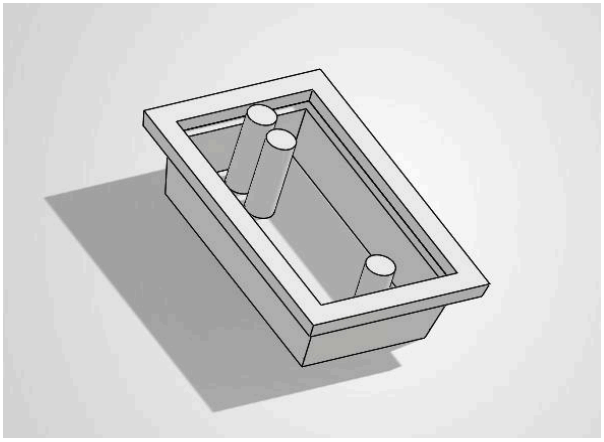


Figure 4: Ice Cube Mold

Design 2 (Water-Glycerol Channel Adjacent): This design builds on the smooth, single-outlet design shown in Figure 2 by adding a cooling channel alongside the collagen channel. A 50:50 water–glycerol solution at approximately -23 °C would flow through it, drawing heat from the collagen through the 50 μm wall separating the channels. A future version could place a cooling channel on each side of the collagen channel to increase cooling.

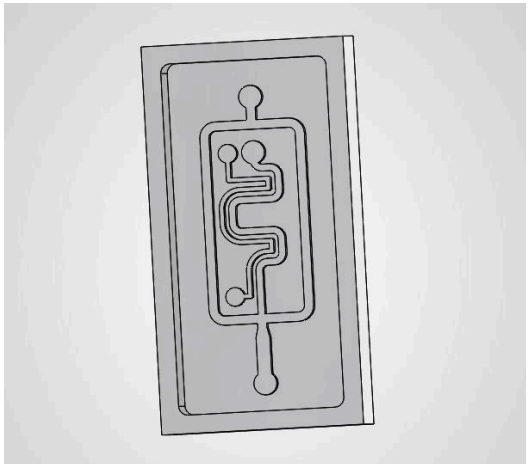


Figure 5: Water-Glycerol Channel Adjacent Design

Design 3 (Water-Glycerol Attached PDMS): This mold design mirrors the smooth, single-outlet design of the collagen and oil channeled PDMS molds; however, it is designed to flow a 50:50 water–glycerol solution at approximately -23 °C through it. The resulting PDMS design would be bonded to the same glass as the droplet channel PDMS and would flow directly across from it, drawing heat from the collagen through the glass separating the channels. This design could be elevated by exchanging the glass platform that both materials are bonded to for a similar but more thermally conductive material.

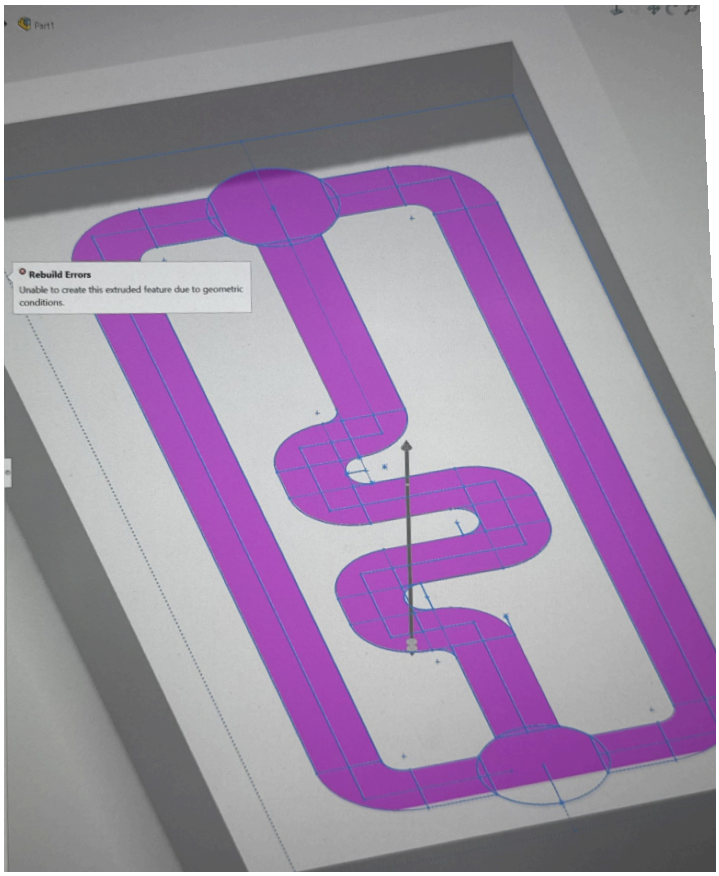
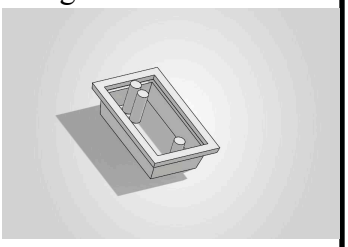
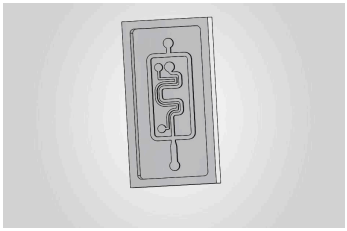
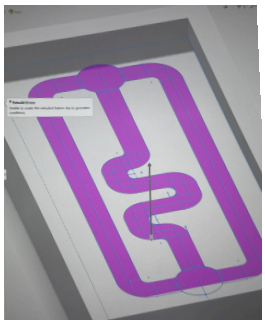


Figure 6: Water-Glycerol Attached PDMS Design

Matrix 2: Collagen Cooling Mechanism

Criteria (Weight)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Design Sketch	Design 1: Ice Cube Mold 		Design 2: Water-Glycerol Channel Adjacent 		Design 3: Water-Glycerol Attached PDMS 	
Cooling Effectiveness (25)	4/5	20	4/5	20	3/5	15
Repeatability (20)	3/5	12	5/5	20	5/5	20
Sterility (20)	3/5	12	4/5	16	4/5	16
Usability (15)	4/5	12	5/5	15	4/5	12
Durability (10)	2/5	4	5/5	10	4/5	8
Ease of Fabrication (10)	3/5	6	5/5	10	5/5	10
Total (100)	66		91		81	

Criteria Description and Rating Rationale

Criteria 1 - Cooling Effectiveness:
Cooling effectiveness is necessary as the highest weighted criteria because the entire system must be kept cool to avoid collagen polymerization. If the collagen hydrogel begins polymerization in the microfluidic chip, it can lead to clogging of the channels. Then, the entire

chip would need to be thrown away and remade. To prevent this and make the final product as effective as possible, a sufficient cooling mechanism is necessary.

- Ice Cube Mold: The ice cube cooling method is projected to be an effective method due to the direct contact between the ice cube and the microfluidic chip. This limited barrier between the freezing ice cube and the microfluidic chip allows for high transfer of the cold temperature to the collagen hydrogel in the channels. This design scores a 4 out of 5 in cooling effectiveness because as the ice cube melts, the cooling strength will decrease and eventually disappear. This is not a permanent cooling method.
- Water-Glycerol Channel Adjacent: The water-glycerol channel adjacent to the collagen channel provides a high cooling effectiveness as well. The water-glycerol solution can be kept as cold as -23 °C before it freezes. This provides a much colder ambient temperature than the ice cube. Additionally, this cooling solution is permanent because the water-glycerol solution will stay in the channel and not melt. This design scores a 4 out of 5 in cooling effectiveness because although the cooling power is strong, the cooling channel is separated from the collagen channel by a thin barrier of PDMS.
- Water-Glycerol Attached PDMS: The water-glycerol attached PDMS mold is a similar solution to the adjacent channel above. This design provides a greater area covered in the -23 °C water-glycerol solution; however, it is separated from the collagen channel by the glass that both the microfluidic chip and the water-glycerol PDMS chip will be bonded to. Thus, the cooling effectiveness will be lower due to this greater distance. Research can be done into a material other than glass that can better transmit the cooling effect through to the collagen. Yet, as of now, this design scores a 3 out of 5 in cooling effectiveness.

Criteria 2 - Repeatability:
The repeatability of each design refers to its ability to repeat its cooling effects quickly on the next mold without degradation of the effectiveness of the design or the system itself. This is mainly classified by the way in which each design cools the mold. It is extremely important for the cooling devices to maintain a temperature at or below 4°C, as the collagen gelation process begins affecting the structure and viscosity of the fluid at any temperature higher than 4°C. Repeatability is, therefore, paramount to the success of the overall system and should have a high standard in each design to keep the temperature constant and below the maximum value.

- Ice Cube Mold: The “Ice Cube Mold” has the lowest score within the repeatability criteria because of the liquid that it is using. Water does not stay frozen for a long period of time, especially when kept in a room-temperature space. This shortens the droplet generator’s operating cycle and requires the water to be refrozen often. On top of this, water can be a highly corrosive substance if kept within a confined space, such as the proposed mold. Overall, this gives this design a 3/5 rating when considering repeatability.

- Water-Glycerol Channel Adjacent: This design utilizes a Water-Glycerol compound instead of standard water to cool the collagen flowing through the mold. This gives the "Water-Glycerol Channel Adjacent" design a 5/5 rating in the repeatability category. Water-Glycerol is able to maintain lower temperatures than ice and for a longer period of time, making it much more favorable in a situation such as this. The droplet generator can then run for longer periods, generating more collagen beads and providing a greater output volume. The Water-Glycerol will also be situated within the channels surrounding the flow of the collagen, reducing its movement within the mold and reducing stresses on the channels it's held within, increasing the mold's lifespan.
- Water-Glycerol Attached PDMS: Once again, Water-Glycerol is used as the focal point of the "Water-Glycerol Attached PDMS" design, giving it a 5/5 score. For repeatability, Water-Glycerol is an extremely favorable fluid to use because of its low freezing point and slower heating than water. Because the fluid doesn't phase-change within the temperature range it will be held in, keeping the fluid steady under the PDMS mold the collagen is flowing through will ensure the integrity of the mold.

Criteria 3 - Sterility:
Sterility refers to keeping the collagen and microfluidic system free from unwanted microorganisms, such as bacteria and fungi, that could interfere with the experiment. In our project, maintaining sterility is especially important because the collagen beads will contain living cells, and any contamination could affect cell survival, immune-cell behavior, collagen gel formation, and the reliability of our lymph-node microphysiological model. Achieving 100% sterility is practically impossible outside of highly controlled laboratory environments, but the goal is to minimize contamination risk through methods such as sterilized materials, closed microfluidic channels, and proper handling procedures. Therefore, our design should focus on creating a system that maintains a highly sterile environment while still allowing efficient collagen droplet generation and cell encapsulation.

- Ice Cube Mold: The Ice Cube Mold design has the advantage of being simple and easy to clean due to its open and accessible structure. Since there are fewer enclosed channels, it is easier to remove residues and perform basic sterilization before use. However, because the ice cube is exposed to the surrounding environment during preparation and handling, there is a higher risk of contamination.
- Water-Glycerol Channel Adjacent: The Water-Glycerol Channel Adjacent design provides better sterility control because the collagen flow path is enclosed within the PDMS device, reducing exposure to external contaminants. The separate cooling channel also allows temperature regulation without directly interfering with the collagen pathway. However, sterilizing the internal microchannels can be challenging because small channels may trap residues or contaminants, requiring careful flushing and preparation before use.

- Water-Glycerol Attached PDMS: The Water-Glycerol Attached PDMS design creates a more controlled and enclosed environment, which helps reduce contamination during collagen processing. The integrated structure is beneficial for maintaining sterility during cell-containing collagen droplet generation because it limits external exposure. However, the more complex channel network makes cleaning and sterilization more difficult, as internal surfaces are harder to access. Additionally, some sterilization methods may affect PDMS properties or bonding.

Criteria 4 - Usability:
As with the microfluidic molds above, the ultimate goal of the project is to create a functioning device for Dr. Sanchez de Diego. Therefore, the usability of all components in the project is key. The collagen cooling mechanisms are ranked based on their projected ease of use and ability to make the research workflow as simple as possible. However, usability is weighted slightly lower for these designs due to the higher importance of cooling effectiveness, repeatability, and sterility.

- Ice Cube Mold: The ice cube mold is highly usable; however, it is lacking in a few areas. The process of creating the mold is simple, and filling it with water to produce the ice cube is not difficult. The ice cube sits on top of the microfluidic chip and provides cooling to the entire system. However, this design is not perfect in usability because the melting ice is a factor to consider that adds a troublesome aspect to the process. The researcher would need to contend with cleaning up the water that spills in the biological safety cabinet due to the melted ice. Therefore, this design scores a 4 out of 5 in usability.
- Water-Glycerol Channel Adjacent: The water-glycerol channel adjacent to the collagen channel provides a unique engineering solution and scores a 5 out of 5 in usability. The water-glycerol solution is easily fabricated in bulk and can be stored in a -23 °C freezer when it is not needed. Then, the process is as simple as using another syringe to fill the adjacent channel with solution and leave it there as a stagnant cooling channel.
- Water-Glycerol Attached PDMS: The working principle of this design is similar to the water-glycerol adjacent channel design. However, this design adds complexity in the fact that it requires bonding this new PDMS chip to the other side of the glass that the microfluidic chip is bonded to. This makes the entire system bulkier. Therefore, this cooling mechanism design scores a 4 out of 5 in usability.

Criteria 5 - Durability:
The durability of each design mainly depends on each design's ability to withstand wear and tear over repeated use. The material used to make the molds, the bonding mechanisms between pieces, and the fluids being held within each design are considered. A longer-lasting cooling mechanism will greatly improve the ease of use of the overall system and the quality of life of the operator, as they will not have to refabricate the cooling system between uses of the droplet generator.

- Ice Cube Mold: Though the ice cube mold has a resin mold in which the design would hold its form, since the actual coolant is an ice cube, it will melt over time, which would ultimately be inefficient in terms of long-term durability per trial. The ice cube mold design receives a 2 out of 5 in durability.
- Water-Glycerol Channel Adjacent: The Water-Glycerol Channel is perfectly suited for durability purposes. Since it is adjacent to the primary flow channels, it would simply flow liquid alongside it, minimizing any sort of durability constraints such as melting or cracking. Thus, this design scores a 5 out of 5 in durability.
- Water-Glycerol Attached PDMS: Similar to the previous design, since the liquid coolant is flowed through a channel, there are no other factors that contribute to its durability. However, one durability consideration may be the bonding of this separate PDMS chip to the other side of the glass. This added bulkiness could lead to decreased durability so this design scores a 4 out of 5.

Criteria 6 - Ease of Fabrication:
Fabrication is an important part of our design matrix. Since each device will likely need to be remade before use because of sterility concerns, we need a process that is easy to repeat. Ideally, fabrication should be efficient and produce consistent devices with limited variability.

- Ice Cube Mold: The ice cube mold may be difficult to remove the ice from. If the resin is not flexible enough to release it, the ice could become stuck or crack, making it unusable.
- Water-Glycerol Channel Adjacent: The channel-adjacent water–glycerol design is relatively easy to fabricate, requiring printing and post-processing. Once a working procedure is established, this cooling method should be straightforward to reproduce.
- Water-Glycerol Attached PDMS: Like Design 2, the cooling feature is built into the device, but it is attached to the opposite side of the glass from the collagen and oil droplet generator. The main fabrication concern is connecting inlet ports on both sides of the glass. The device may need to be suspended or use a different tubing connection.

Droplet Collection Incubator Designs

Design 1 (Simple Plate): This droplet collection incubator is a simple plate design 3D printed from a heat-resistant filament like polycarbonate. There is a channel running through the surface of the plate in a spiral where the insulated, heat-resistant wire is stored, covering the majority of the surface of the plate in relatively tight wraps. It will be set to maintain 37 °C but is unadjustable and not self-regulating, meaning it will not be able to dynamically maintain the desired temperature. Additionally, heat is only transferred into the catch plate for the microdroplets through the bottom of the plate; there is no heat transfer around the sides of the plate.

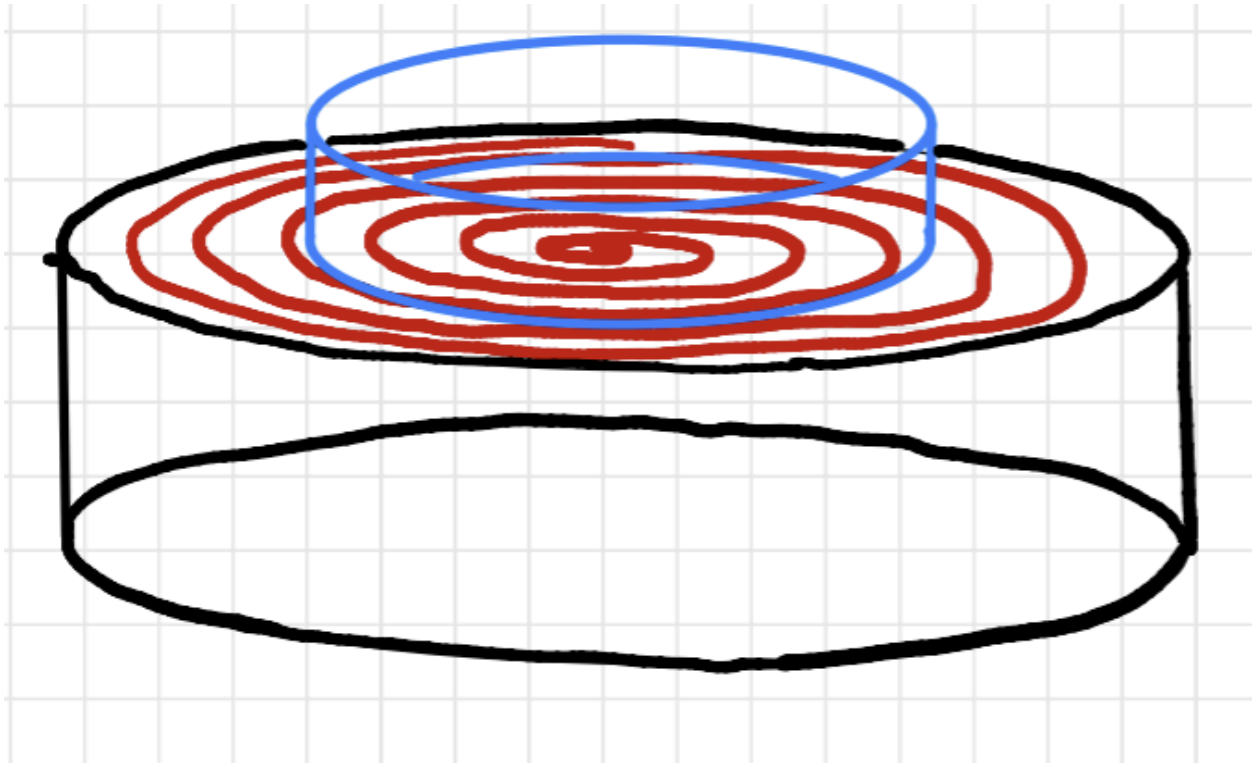


Figure 1: Simple Spiral Plate Design

Design 2 (Thermo Cloth): This design has the same cylindrical plate design, but instead of resting on top of the plate, the droplet collection dish is sunken into a cutout in the plate. This is possible because the resistance wire is stored inside a cloth covering. This protects the material on either side, ensuring the protection of all elements of the design while making the heating surface a moldable shape. This means that when the collection dish sinks into the cutout, the thermoregulated cloth is pressed against the bottom and sides, increasing the amount of surface area as well as the amount of contact of the heated surface with the dish. Additionally, this design now has a closed feedback loop between a thermocouple that relays the current temperature of the cloth to a simple computer that then raises or lowers the temperature accordingly to maintain the desired temp.

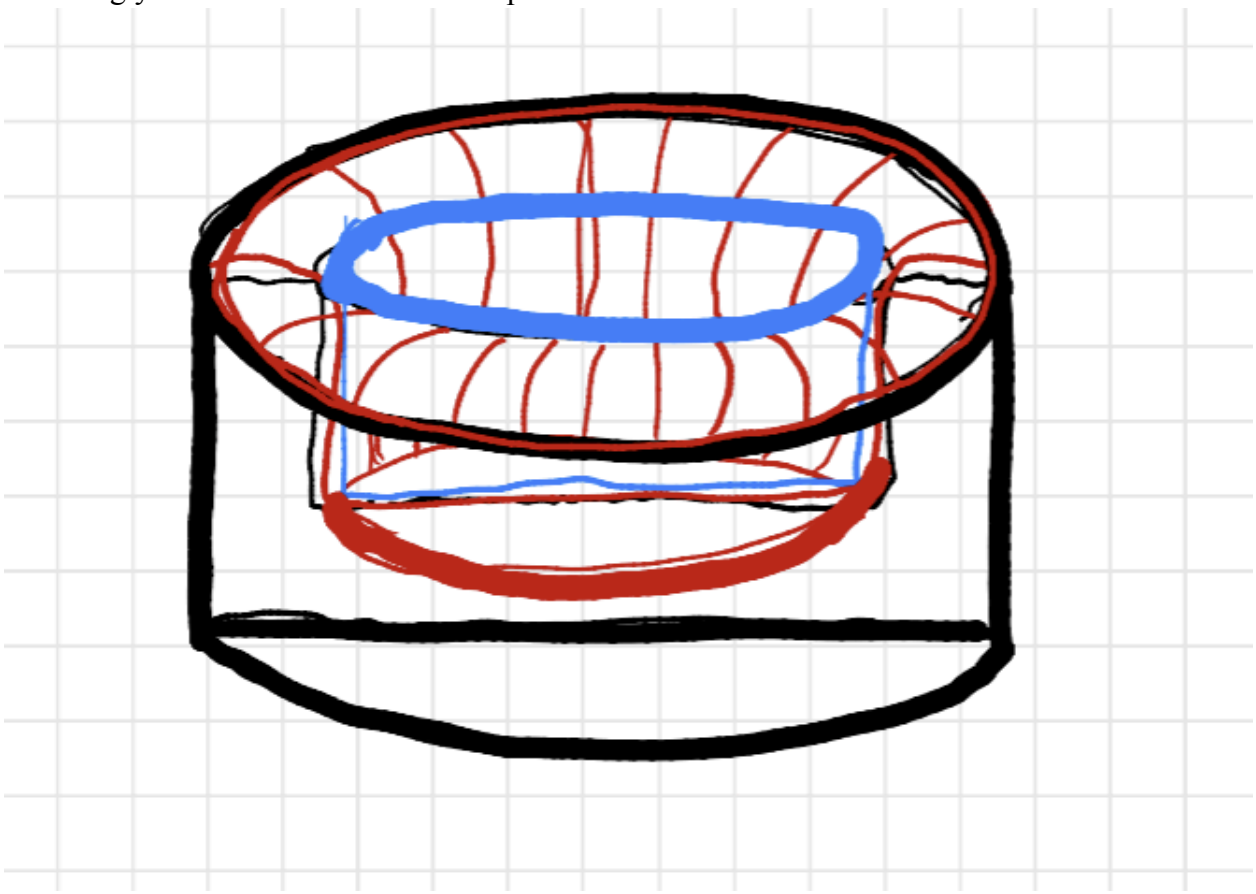


Figure 2: Sunken Cloth Contact Design

Design 3 (Fluid Chamber): This design is more complex than the previous two designs. It uses the same sunken dish hold as the previous design, but in this case the dish is directly contacting the 3D printed model. The inside of the square chamber has a highly thermally conductive fluid that relays the embedded resistance wires' heat evenly throughout the entire solution. This design also has the dynamic self-thermoregulation components like the last design.

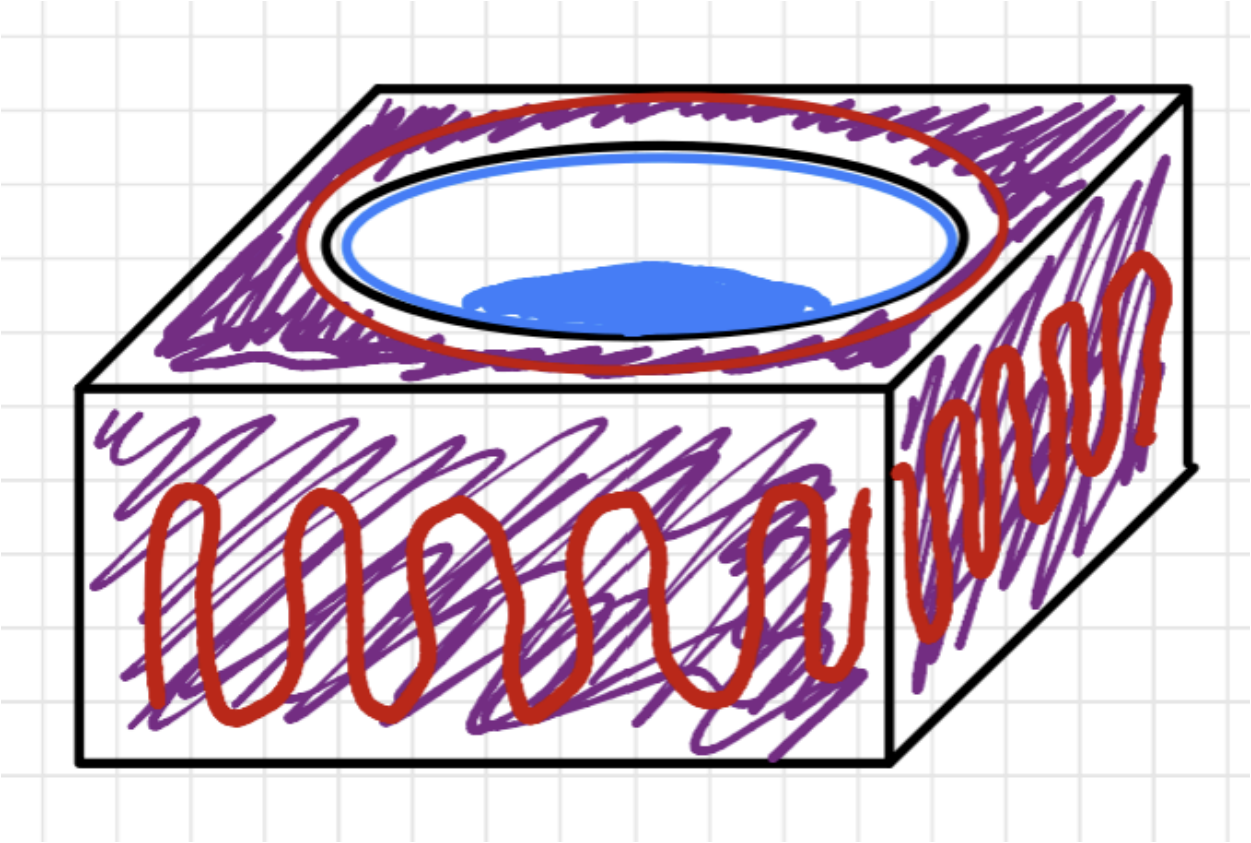
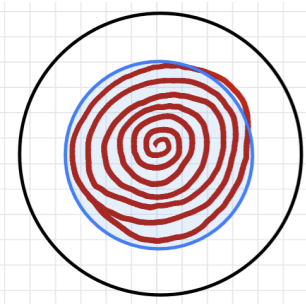
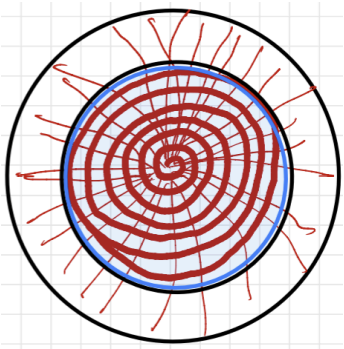
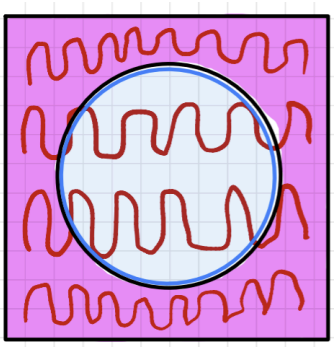


Figure 3: Fluid Chamber

Matrix 3: Droplet Collection Incubator

Criteria (Weight)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Design Sketch	Design 1: Simple Plate 		Design 2: Thermo Cloth 		Design 3: Fluid Chamber 	
Heat Transfer (25)	2/5	10	5/5	25	3/5	15
Heat Control (20)	1/5	4	4/5	16	5/5	20
Usability (20)	4/5	16	3/5	12	4/5	16
Sterilizable(15)	5/5	15	2/5	6	3/5	9
Fixable (10)	5/5	10	4/5	8	2/5	4
Ease of Fabrication (10)	5/5	10	4/5	8	1/5	2
Total (100)	65		75		66	

Criteria Description and Rating Rationale

Criteria 1 - Heat Transfer:
Heat transfer is vital and the most important factor in this design because the device needs to be able to conduct accurate amounts of heat into the solution so that it can maintain temperature long enough for all of the collagen to polymerize. Slow or ineffective heat transfer would render the device useless.

- Simple Plate: This design is the least efficient in terms of heat transfer. The heat exchange can only take place between the bottom of the droplet dish and the wire. The rigid wire will also be limited in the amount of surface area it can contact

- Thermo Cloth: The heat transfer of this design is superb; the thermoregulated cloth will apply even heat to the entire outside and bottom of the droplet dish. Additionally, the moldable form of the cloth will maximize contact area on the dish and, in turn, heat transfer.
- Fluid Chamber: This design has the most evenly distributed heat transfer, but it will be limited by the necessity of transferring heat from the internal fluid through the 3D-printed material.

Criteria 2 - Heat Control:
Heat control is essential, and it is the entire role of the incubation device. All of the designs possess heat control to an extent because we can calculate the power output using Ohm's law. By varying the amount of current and resistivity of the wire, we can create a desired power output and therefore temperature. The control aspect is altered by not having this power output be static. A closed feedback loop using a thermocouple and a microprocessor would enable a dynamically self-regulating device

- Simple Plate: No thermoregulation, completely static output without the thermocouple and microprocessor.
- Thermo Cloth: This design has dynamically regulating components that allow for control, but the heat is not guaranteed to be equally dispersed, meaning wherever the thermocouple sits is the only region that will be regulated with accuracy. If there are cooler or warmer sections of cloth, the device will not have a reading on them, and they will not be regulated.
- Fluid Chamber: This design has dynamically regulating components, allowing for control; additionally, the equally dispersed heat throughout the fluid in the chamber means accurate control of the temperature of the entire device.

Criteria 3 - Usability:
This is important because the device needs to balance the ease of use with the effectiveness of the design. Another important component is the stability/security of the device in its incubation zone, should it get knocked around while in the lab.

- Simple Plate: This design has high usability; the dish is placed onto the heated plate. The drawback of this design is that there is nothing securing the dish in place, meaning that it could be knocked off of its platform.
- Thermo Cloth: This device got a poor usability score because of the multiple moving parts. Ensuring that the blanket is in the proper position, and that the dish is sitting evenly in the cutout with the blanket evenly distributed around, is a more intensive process than either of the other two designs require. Yet, once set up, it will be secure.

- Fluid Chamber: This is the most usable; the collection dish is slid into the cutout, and it is maintained securely there throughout the experiment. It does, however, lack a designed method of removing the droplet collection dish from the cutout.

Criteria 4 - Sterilization:
A sterilizable design is essential because the device will be used in a sterile biological safety cabinet environment with living cells. The main factor to consider here is exposed electronics and whether they would be sterilizable or not.

- Simple Plate: This design has major advantages in terms of sterility. There are fewer electronics to enclose during the process because it does not include the electronic feedback loop component of the other designs. This means that the only problem is the sterility of the platform itself. This should not be a problem; if the correct materials are used, it will all be able to run through an autoclave.
- Thermo Cloth: This design will be the most difficult to sterilize because both of the components will face challenges. The feedback loop will require electronics, which must be sealed to survive the sterilization process; additionally, the cloth will need to be designed in such a way that it can be effectively sterilized. Ideally, everything can be autoclaved, but this may be difficult for this design in particular.
- Fluid Chamber: This design only possessed one of the roadblocks to being easily autoclaved. The platform itself will be entirely 3D printed, so it is able to be autoclaved. This design, however, does have a feedback loop, so sealing the electronics is a concern.

Criteria 5 - Fixable:
Fixability is relatively important, an independent researcher must be able to easily troubleshoot and repair any issues that arise. If a design were to break and repairs were extremely complex or expensive, it would potentially be more trouble than it is worth, distracting from research goals.

- Simple Plate: Very simple and fixable design; each part can be replaced independently without damaging any other part, and all can be done so cheaply.
- Thermo Cloth: This design is also very fixable, as each part can be replaced independently without damaging any other part. The thermoregulation components will be more difficult to isolate as the cause of a problem.
- Fluid Chamber: This device would be very durable as there are no external components, but if something were to break, it would be essentially unfixable. Destroying and then breaking the bond that contains the internal fluid would likely destroy the seal, and if internal components break, the whole device would have to be replaced.

Criteria 6 - Ease of Fabrication:
While the body of all three designs uses 3D printing for the main component, the rest of the device and its ease of fabrication vary dramatically between the first, second, and third devices. This makes it an important consideration given our time constraint and budget.

- Simple Plate: This device would be very straightforward to manufacture. There is the 3D-printed model and then wire wrapping. Both of these components are able to be procured and put together without trouble.
- Thermo Cloth: This design has the added component of embedding the resistance wire into the cloth, which is an important consideration but won't be dramatically more difficult. This design, however, does include the hardware and software associated with thermoregulation. This is important as it will add an additional layer to the physical fabrication.
- Fluid Chamber: This design is more complex than the others and would be considerably more difficult to manufacture. Purchasing and sealing the fluid inside the 3D-printed chamber with equally distributed resistance wire would not be easy, and the wires running in and out would need to be tightly sealed. This design also includes the thermoregulation components.