**Logbook**

**December 22**

Started brainstorming ideas. Started leaning towards some sort of experiment project, medical related preferably.

**December 29**

Settled on the idea of kidney dialysis because we found the process quite interesting.

**January 3-29**

Created all our research questions and started to research

What are kidneys and how do they work?

What is kidney dialysis?

What are Kidney membranes?

What are Synthetic membranes?

What are Cellulose membranes?

**January 3**

**Began research on kidneys and what they do**

Kidneys are a pair of organs in the body. They filter our blood by removing excess waste and extra water, they also help keep chemicals such as potassium, calcium and sodium levels balanced in the body. They also remove acid produced by cells in your body maintaining that same balance. WIthout this, nerves, muscles and other tissues may not do their designated jobs properly. Kidneys also create hormones that regulate your blood pressure, create red blood cells, and help keep your bones strong and healthy.

Kidneys contain millions of tiny filtration devices called **nephrons**. Every nephron includes a glomerulus and a tubule. A glomerulus is a specially modified blood vessel that filters blood in the kidney to create urine. A tubule is one of millions of tiny structures within your kidneys that collect urine from the glomeruli. First, blood flows into the kidney from the renal artery. When it reaches the glomerulus, it filters any large molecules such as proteins or blood cells, allowing everything else (minerals, nutrients, excess water) to pass into the tubule. The tubule and a blood vessel run alongside each other, and once the filtered blood enters the tubule, the blood vessel absorbs most of the water and the nutrients and minerals that the body requires. The tubule also removes excess acid. The remaining fluids and waste are turned into urine. The blood then flows out of the kidney using the renal vein.

**January 11**

**Researched the dialysis process**

Kidney dialysis is a treatment that filters your blood when your kidneys are no longer healthy enough to do so. Without proper filtration, waste and toxins build up in your bloodstream, causing nausea, vomiting, weight loss, difficulty concentrating and fatigue. There are two main types of kidney dialysis, hemodialysis and peritoneal dialysis.

Hemodialysis is a three to five hour process in which a machine removes blood from your bloodstream, filters it through a dialyzer and returns the freshly cleaned blood to your body. This process can be done at home or in the hospital. Before the procedure, patients will undergo a minor surgery to access the bloodstream easier. Surgeons can do this by either connecting an artery and vein in the patient’s arm, or using a soft hollow tube called a graft to connect the artery and vein. This process makes dialysis access easier, as well as increasing the speed of blood flow in and out of the patient's body. During the hemodialysis procedure, the machine first sticks a needle into the patient's arm to access the bloodstream. The blood then circulates through the dialyzer filter, which moves waste into a dialysis solution containing water, sodium, potassium, calcium, magnesium, chloride, and bicarbonate. The blood is then returned to the body through a separate needle in the arm.

Peritoneal dialysis is a treatment that uses tiny blood vessels inside the peritoneum (abdominal lining), to filter blood with the help of a dialysis solution. This solution contains water, salt, and assorted levels of dextrose depending on the condition. Peritoneal dialysis is done at home, and can be automated, using a machine called a cycler or can be done automatically with continuous ambulatory peritoneal dialysis (CAPD). Three weeks before starting peritoneal dialysis a surgeon will insert a catheter (a soft, thin tube), into the peritoneum which permanently stays in place. The first step of peritoneal dialysis is to connect the catheter to one branch of a Y-shaped tube connecting to a bag with the dialysis solution. The solution is then able to flow into the peritoneal cavity. After ten minutes, the tube and catheter are disconnected and the catheter is capped off, sealing the tube. Over a period of around 60 - 90 minutes the dialysis solution absorbs waste and extra fluids from the body. The fluid then has to be drained through the other arm of the Y-tube into an empty bag. Patients using this manual method of peritoneal dialysis will have to do this process up to four times a day and sleep with the solution in their stomach all night. If the patient prefers to do the process at night, a machine called a cycler would pump the fluid in and out of their body while they sleep.

**January 20**

**Briefly researched synthetic and cellulose membranes**

**Synthetic membranes**

Synthetic dialysis membranes are more biocompatible with the human body, meaning they trigger less of an immune response. According to one small study they may be better at lowering beta 2 microglobulin levels, which may be linked to amyloidosis. This is especially true in high flux membranes. Synthetic membranes are also believed to improve triglyceride levels. These membranes are very versatile, as they can be manufactured to be high or low flux, meaning they can accommodate larger or smaller molecules respectively. Amyloidosis risk was lower in another small study using high flux synthetic membranes. Kt/v values (clearance or amount of urea the dialyzer can remove x time over volume (amount of body fluid) are also significantly higher with this membrane. These membranes are significantly more expensive than cellulose based ones by about three to four times, so further research is needed to determine any potential benefit for this large of a price difference

**Cellulose membranes**

Cellulose membranes are primarily constructed from cotton, making them more sustainable. They are also well tolerated by the human body. Another benefit of these membranes is how they are significantly more affordable than synthetic membranes. While dialysis adequacy (kt/v) is reported to be better with synthetic membranes, cellulose does a good job of clearing urea. and creatinine. They are classified as a low flux membrane due to their low permeability to water, creating a poor clearance of molecules larger than urea and creatinine. This reduced clearance could lead to future complications over a prolonged period of time.

**January 29**

**Finished up research, challenges and limitations and osmosis and diffusion**

**Challenges and limitations of dialysis**

Kidney failure can occur when facing diabetes, high blood pressure, kidney inflammation, kidney cysts, inherited kidney disease and maybe a long usage of anti-inflammatory drugs or medications that are harmful for the kidneys. Some people with kidney failure may opt for a different route, like applying for a kidney transfer, or maximum conservative management which entails taking active managements of symptoms, like high blood pressure and fluid overloads. Some risks that could take place during dialysis are low blood pressure (hypotension), high blood pressure (hypertension), muscle cramps, anemia, sleep issues, bone disease, fluid overload, high/low potassium levels, depression, and stiffness and pain in the joints (amyloidosis).

Some of these potential side effects could be solved by a quick change in diet and fluid consumptions. Consuming too much salt or drinking more fluids than recommended by doctors during hemodialysis could lead to worsened high blood pressure, leading to heart problems or a stroke. Fluid gets taken away during hemodialysis, so drinking more than advised in between treatments could end up bringing life threatening issues such as heart failure or fluid buildup in the lungs. As mentioned before, diet is extremely important. A patient that requires hemodialysis, should watch their sodium, fluid, protein, potassium and phosphorus intakes.

**What Hemodialysis can and can’t filter**

Hemodialysis can't fix everything, so here is a deep dive into what artificial kidney dialysis can and cannot filter. Urea is one of the molecules that can be filtered out by hemodialysis, and it is a waste product from protein metabolism coming in at around 60 Da (daltons). Waste from muscle breakdown and nucleic acid metabolism - creatinine and uric acid respectively - can also be filtered out through hemodialysis. Potassium, phosphate, sodium, and calcium, which can come from electrolyte imbalances are also easily filtered by hemodialysis membranes. Ammonia - a waste product from protein breakdown, beta 2 microglobulin - a middle molecule marking dialysis efficiency, and toxins from some medications can also be filtered out by dialysis. Albumin is a molecule that is too large for hemodialysis to filter, coming in at around 66 kDa (kilodaltons). Immunoglobulins are also too large to be filtered out, and are around 150 kDa large. Fat - soluble toxins like vitamins, antibiotics and anti-anxiety medications also cannot be filtered because they are lipophilic protein bound toxins. Lastly, certain medications such as digoxin (heart failure medication) and warfarin (blood clot preventing medication) cannot be filtered because they are highly protein bound drugs. The main reason why membranes have a hard time filtering out these things is because of their complex molecular structure, making it difficult for them to pass through the membrane.



**Osmosis/Diffusion**

Osmosis is a type of diffusion that is specifically made for water molecules moving across a semipermeable membrane. Osmosis is when molecules flow from an area of higher concentration to an area of lower concentration to reach an equilibrium or an isotonic state. There are also multiple tonicities that are part of osmosis. Hypertonic, hypotonic and isotonic states. Hypotonic is when there is a lower concentration of solute in an area, while hypertonic is a greater concentration and isotonic is an equal amount. Osmosis is a very important phenomenon because it takes place in the kidneys by taking waste products out of the blood. Osmosis occurs from inside of the nephrons in the kidney. A medulla is the largest part of a nephron and it contains a higher osmolality (number of solute particles per litre of solution). The water travels from inside the nephron tubes, across a semipermeable membrane, to the medulla leaving behind concentrated urine. This is due to osmosis. Since the Medulla had a higher concentration of solute particles over the nephron, the water molecules travelled across the semi permeable membrane to reach an isotonic state between the nephron and medulla, leaving behind that urine.

When the kidneys are unable to complete their job correctly, a kidney dialysis machine would help. These machines use osmosis to clear the blood of any toxins or waste materials. In these machines, blood gets taken out of the body from an artery and is pumped next to a semipermeable membrane with the dialysate solution on the other side. These two liquids are pumped in a countercurrent exchange direction. By using the concept of osmosis, the water and small waste molecules in the blood would flow through the semipermeable membrane. Eventually all of the waste would be removed from the blood, and the filtered blood would be pumped back into the body through a vein.

**February 1**

**Came up with hypothesis and variables to go along with our experiment**

**Variables**

Controlled:

* All other parts. Ex. The “blood”, the solution, etc.

Independent:

* Membrane

Dependent:

* Effectiveness of the filtration membranes
* Effectiveness of the model

**Hypothesis**

Our project is about which type of membrane is effective during kidney dialysis. Kidney dialysis is an artificial process that allows for blood purification when the kidneys are no longer healthy enough to do so, making the membranes a crucial part of this process. We have chosen to focus on synthetic and cellulose membranes. We hypothesize that if we attempt to construct an at home dialyzer model, then the mock blood solution will be filtered to some degree because of the large pore sizes in our take of a cellulose membrane model, which was a cheesecloth.

**February 3**

**Conducted further research on dialysis membranes**

We talked to a doctor for this and learned that the better membrane depends on the situation of the patient

**February 5**

**Brainstormed model ideas**

**February 7**

**Wrote and listed materials and procedure to correctly conduct our experiment**

**Materials**

* Plastic cylindrical container
* Metal knife
* A flame (to heat up the knife)
* cheesecloth/cotton blanket
* Hot glue gun
* Plastic tubing
* Waste collection containers
* Sharpie
* scissors
* Water pump
* Funnel
* Stand for the model to sit on
* Blood solution (3 spoons water, 6 spoons glycerin, 1 tsp Coffee grounds, 3 spoons coffee)
* Saline solution (Water, 1 ½ teaspoon salt, ½ tsp sugar)

**Procedure**

* Gather materials. Plug in your hot glue gun so it has time to warm up
* Take the lid off of the container, and light a candle or turn on the stove
* Heat up the knife so it can easily glide through the plastic, melting it away. You will need to put the knife in the flame repeatedly between passes through the plastic
* Continue to do this until you have split the container down the middle. DO NOT CUT THE LID IN HALF
* Next, grab your cheesecloth and cut a section big enough to stretch over one half of the container. Leave some space around the outside, as you can trim the excess later.
* Start with a long side of the plastic half, and put a small amount of glue on the edge. Press the cheesecloth into the glue so that it stays. Repeat for the rest of the side.
* After the first side has set for a bit, move onto the long side opposite to the one you just did. Repeat the same gluing process, however this time ensure that you are pulling the cheesecloth tight across the plastic. The tighter it is, the better
* Next, glue the cheesecloth to the bottom of the plastic half. Keep pulling it tight, but not as tight as before because it has the two sides supporting it. The cheesecloth should be like a trampoline, tight and bouncy but not completely taught.
* Let the glue set for 1-2 minutes, and then grab the other half
* Trim the sides of the cheesecloth so that there is a minimal amount around the sides, but be careful not to cut the glue holding it together. Do not over-trim the top, because we will need to glue the membrane to the lid later.
* Put some glue on top of the side that you just attached the cheesecloth to. It should be a sandwich, with the plastic halves on either side and the membrane in the middle. Make sure to line up the threads so that the lid can be screwed on again. Once the other half is attached, go back and make sure to fill any holes or bubbles with hot glue to prevent leaking.
* Test with the lid to be sure you can screw it on. If there is melted plastic in the way then cut it off.
* Once you are sure you can screw the lid on with ease, you need to glue the membrane to the top of the lid. We did this by putting some hot glue on the edge of the cheesecloth and then quickly screwing the lid on. We then held the body upside down (lid on the table) so that the glue could flow down and adhere to the lid like we want it to.
* Once all the glue is dry, we need to cut holes for the tubes to go in. Now that the body is split into two halves, a top and a bottom, we're going to need to make four holes. An entrance and an exit hole for both the chamber on top of the cheesecloth and underneath the cheesecloth. These holes cannot be too big, otherwise it will be difficult to fill them in later. Frequently check with the tubing to see if you have removed enough plastic. The tubes should fit in snugly. The blood will enter on top of the cheesecloth through a funnel, so this hole will most likely need to be larger
* Grab your tubing, and with a sharpie trace the size of the tube where you would like to make the hole. The exit holes will need to be lower because water does not flow up. Keep in mind that the sharpie has a certain thickness, so you will need to melt the plastic inside of the markings
* To cut these holes you will need to reheat your knife. The method we used to cut away the plastic was to poke the knife in the center of the hole, then rotate it until all the excess plastic moved away.
* The next thing you'll need to do is measure how long you want your tubing to be. Set up your machine at an angle so the fluids can flow down, and measure how long the distance is from your machine to the waste containers. Cut a bit extra than what you think you'll need. The tubing is easy to cut, so scissors should suffice.
* Now that we have the waste collection tubes, we need only one more to connect to the water pump, as the blood will flow in through a funnel. Measure what you will need, but cut about an inch or two more just in case.
* Next, prepare your solutions in the remaining two containers. For the blood, grab a plastic spoon (not for cooking) to measure. Mix 3 spoons of water, 6 spoons of glycerin, three spoons of coffee, and about a teaspoon of coffee grounds. For the saline solution, pour into the container about a half cup of water, 1 ½ teaspoons salt and about a ½ teaspoon sugar.
* Now we need to set up the machine. Grab some cardboard and create a stand so that the body of the model is at an angle. We used the box from the water pump as the base and some excess from the delivery box to create a triangle so that the model could sit at an angle
* Attach the body to the stand. We used hot glue. Be careful though, depending on the plastic, the heat of the glue could manipulate its shape.
* Once the body is attached to the base, attach the tubes into the holes. Be sure to seal them with something, otherwise the liquids will flow out of the machine
* Insert the funnel into its respective hole
* Set up the waste collection containers so that the tubes sit inside them. This will maximize waste collection
* Attach the other side of the saline entrance tube toi the water pump. Place the pump inside the saline solution.
* Once you are ready, pour the blood and pump the saline into the model simultaneously. This may be a two person job
* Observe how the cheesecloth is filtering the blood.
* For cleaning up, rinse out the model and set it somewhere it can dry. Run some clean water through the pump to cleanse the inside, and place everything in a safe spot.

**February 11 - 12**

**Bought and gathered necessary materials for our model to work**

**February 13**

**Determined variables for our experiment**

**Variables**

Controlled:

* All other parts. Ex. The “blood”, the solution, etc.

Independent:

* Membrane

Dependent:

* Effectiveness of the filtration membranes
* Effectiveness of the model

**February 15**

**Set up our model in the correct ways so it can function**

**February 16**

**Conducted our experiment with all the solutions, as well as made observations**

**Observations**

When our model was running, the saline solution flowed through the machine very quickly, whereas the blood pooled at the bottom while it was filtering itself. The blood started off with many coffee grounds floating around in it, and when it came out the other end of the model dialyzer there were significantly less grounds in the blood. While they did not penetrate the membrane like traditional dialysis, they did get stuck, filtering the blood to some degree. There was a small break in the seal near the bottom of the model dialyser, unfortunately allowing some of the liquid to spill out onto the table. The dialysate solution changed colour significantly, as it went from having no colour to being a light shade of red. We think this is because of some of the blood and coffee that crossed the membrane through the mock dialysis process. Before the dialysis process, the saline had a pH of 7.33 and the blood's pH was 6.7. After both fluids went through the machine, the saline changed to 7.30 and the blood changed to 6.69,. While these changes are very minor, something did happen when the blood and saline went through the machine.

**February 20**

**Finalized observations and wrote analysis**

**Analysis**

Our model was able to filter out some of the dirty blood to create a cleaner blood solution. We used coffee grounds to simulate urea and waste in the blood, and we found that the grounds got mostly filtered out and the colour of the dialysate changed from clear to a shade of red. While doing the experiment we found that a cellulose membrane does filter out waste materials properly, it changed the pH levels of both the saline/dialysate solution and the blood solution. Although it was a very minor change, it still demonstrated that the machine did work to some degree. Some limitations were the fact that our membrane could only filter out the larger particles, and only some of the smaller particles which could have affected our results. Since we weren’t able to get our hands on a synthetic membrane to compare the two membranes, we decided to use household materials to build this machine to showcase our learning in a unique and resourceful way, and demonstrating how you are still able to build a functioning dialysis machine by using items that can be found at home.

**February 22**

**Listed all sources of error and wrote conclusion**

**Sources of error**

Seal wasn't perfect at the bottom

Membranes are super expensive, couldn't compare them like we originally thought so we decided to make a model instead

Didn’t have access to create an exact replica of human blood

Held plastic too close to flame, altered shape slightly

We successfully demonstrated that our take of a cellulose membrane was able to separate out the waste products from the blood. Our hypothesis was that if we attempt to construct an at home dialyzer model, then the mock blood solution will be filtered to some degree because of the large pore sizes in our take of a cellulose membrane model, which was a cheesecloth.This aligns with the already established knowledge of kidney dialysis showing that the separation abilities of this membrane have been correctly identified. We made a working model of a modular dialysis machine using household materials, making the cellulose membrane out of a cheesecloth. In the future we would also like to physically compare the synthetic membrane by using the same model, as well. However, we found out that if the patient requires dialysis for larger molecules with a more complex structure then a synthetic membrane would be ideal, however if you only needed to dialyze smaller molecules like urea or salt, a cellulose membrane with smaller pores would be more suited for the job. We can also use this model to act as a teaching aid to show the process of kidney dialysis.

**February 23**

**Finalized sources of error and wrote application**

By conducting this project we have expanded our knowledge in the medical field of kidney dialysis, and with this we can teach and show others what we have learned, and the process behind kidney dialysis. If we continue to expand on this project we could try to physically compare multiple membranes, like synthetic non cellulose and cellulose, to see what results we could find. We can also use our model to act as a teaching aid, which can help in the education of the process of kidney dialysis. Further research and studies into this field could lead to a breakthrough regarding improvement in the effectiveness of these machines and lowering the cost of membranes to accommodate lower income patients.

**February 29**

**Cited all of our sources**

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**March 1**

**We put all of our research into slides and printed them off, as well as printed off the pictures from our experiment**

**March 2**

**We put everything onto the trifold, and prepared our acknowledgements**

Mr lahoda, ms rheinstein, Dr Arnav Gupta, parents

**March 4-5**

**Wrote and finalized our presentation script**

**March 6, 10, 11**

**Practiced our presentation**