

# Vasculitis and Aneurysms

**2000** people in the UK are diagnosed with vasculitis every year.<sub>1</sub>

**3.2%** of the global population are affected by unruptured aneurysms.<sub>2</sub>

**Vasculitis** - a group of rare conditions that damage blood vessels by causing inflammation or swelling.

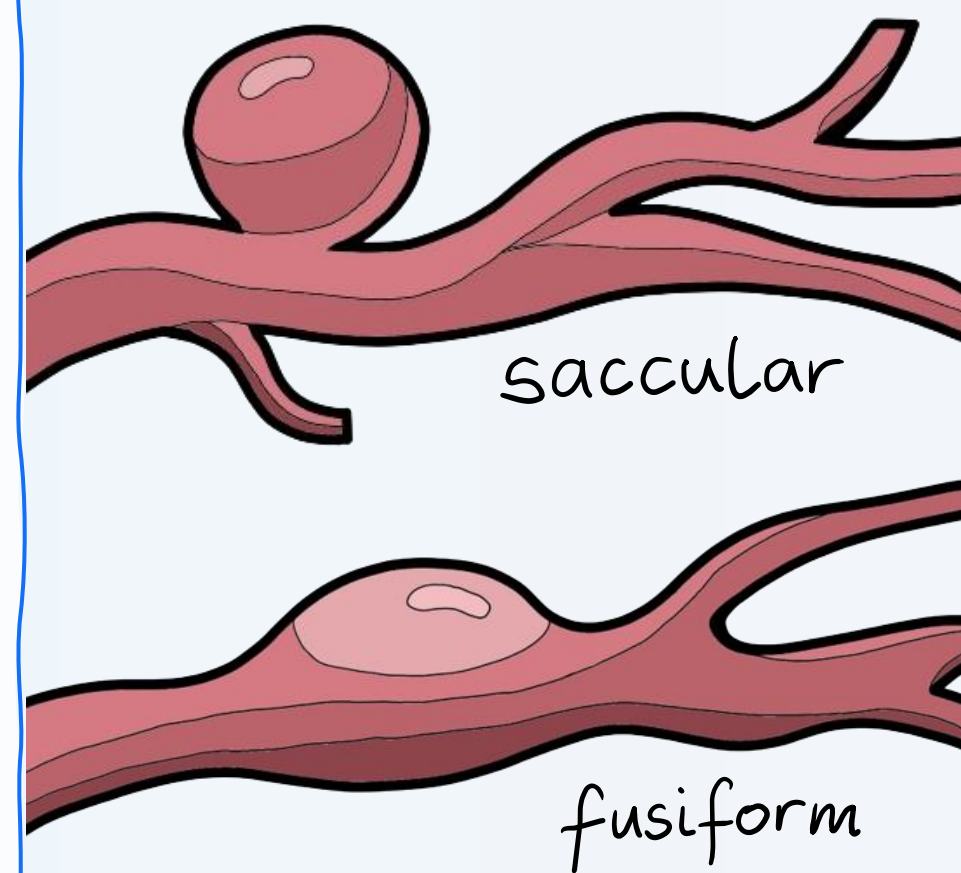
**Aneurysm** - an abnormal bulge or ballooning in the wall of a blood vessel.<sub>4</sub>

Aneurysms when left untreated **may rupture**, with major consequences that can be **lethal**. Several solutions exist, but each come with significant downsides like **long recovery durations** and lack of effectiveness.

An aneurysm is dangerous as the risk of it rupturing or bursting at any time can cause life-threatening internal bleeding. **50%** of cerebral (brain) aneurysms<sub>5</sub> prove fatal as stated by the Brain Aneurysm Foundation.<sub>5</sub>

Vasculitis can lead to the development of aneurysms. Conversely, the **weakening and damage** to blood vessel walls caused by an aneurysm can also trigger an **inflammatory response**, resulting in vasculitis. Both have the potential to block off consistent supply to **vital organs**, resulting in serious consequences.

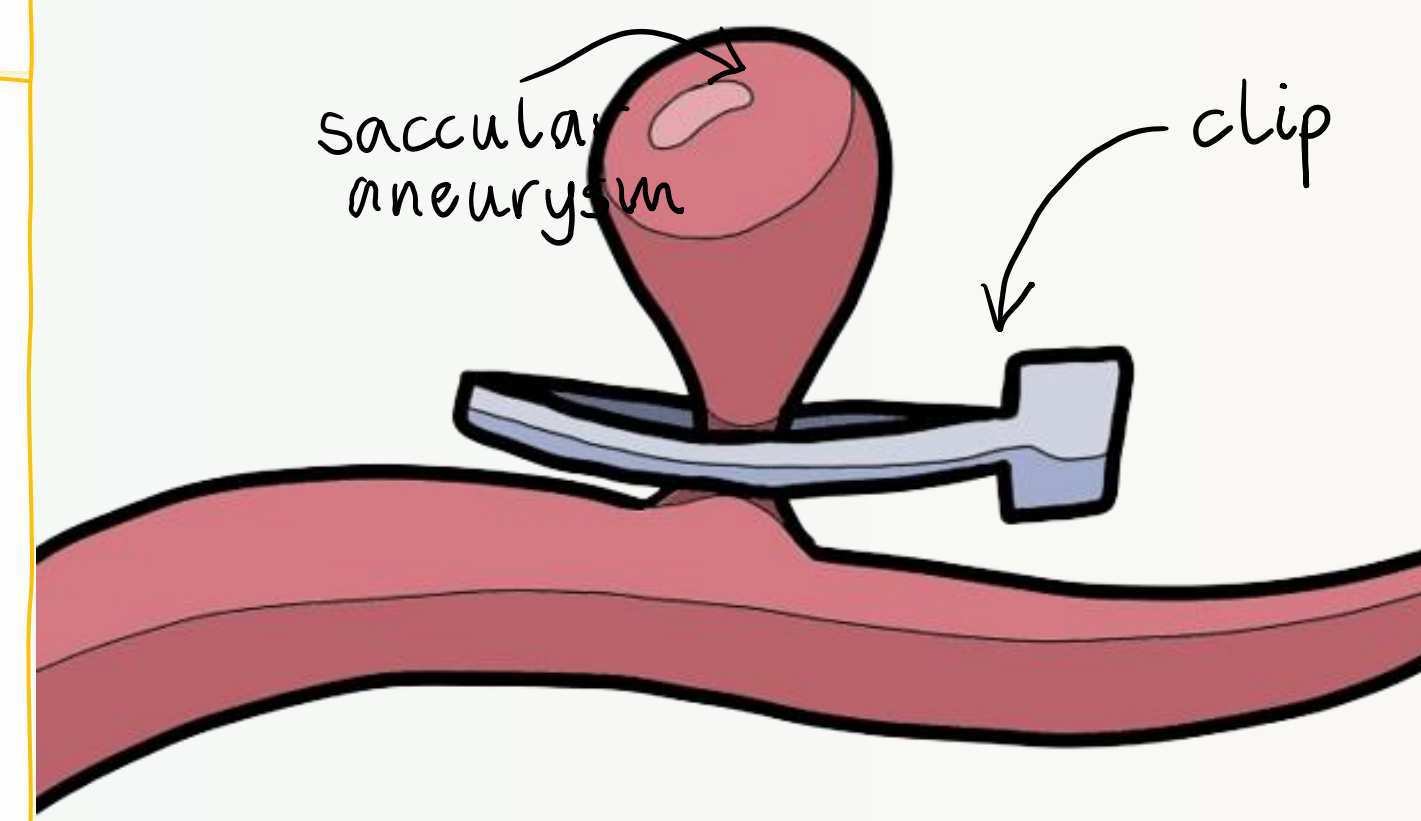
## TWO TYPES OF ANEURYSM



## Existing Solutions

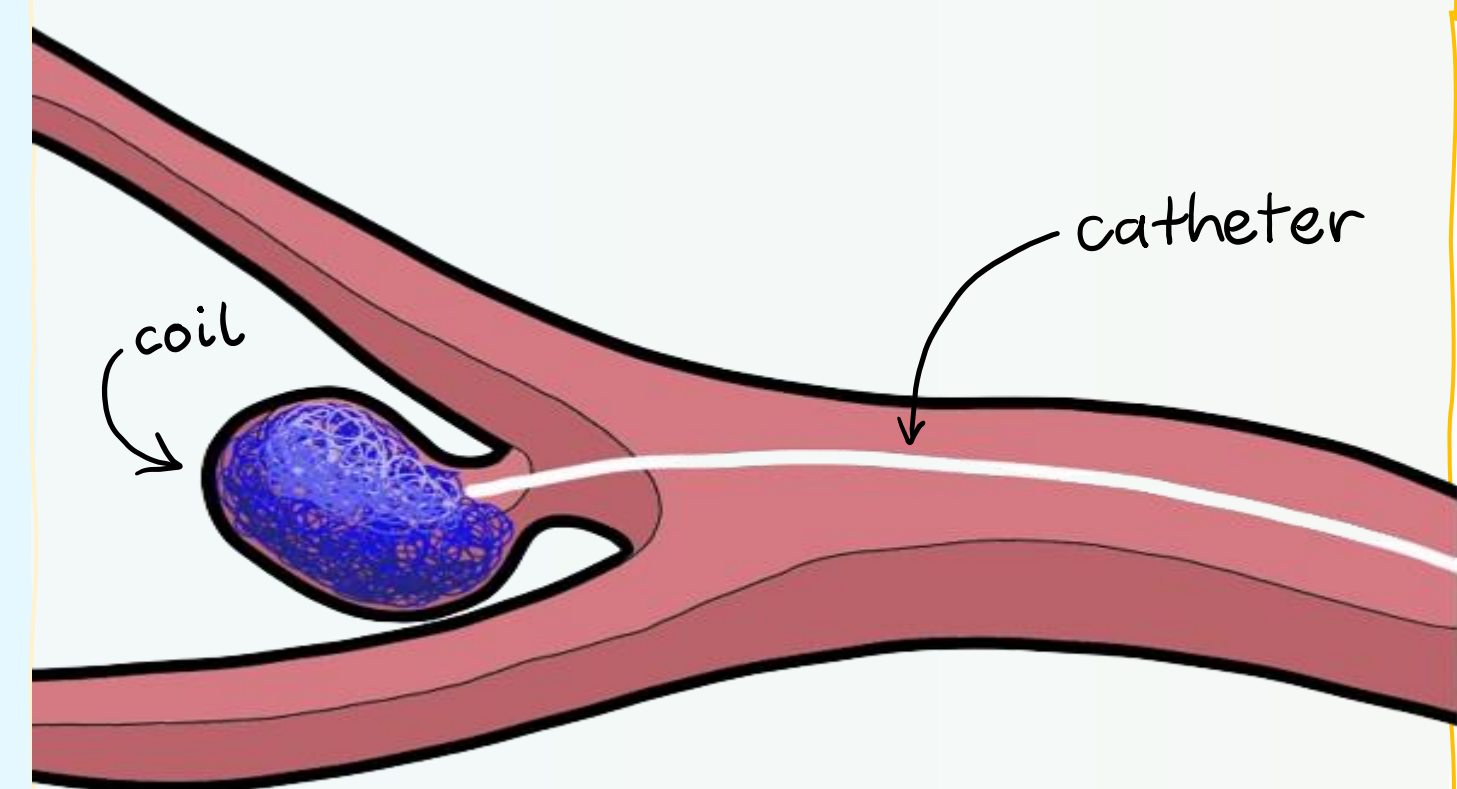
### Surgical Clipping

A **neurosurgeon** (for a cerebral aneurysm) would open the skull and find the **affected artery** - a metal clip is then installed which **prevents blood flow** into the aneurysm. However, there is a **long recovery duration** for aneurysms ranging from **4 to 6 weeks**.<sub>6</sub>



### Endovascular Coiling

This procedure is **less invasive** where a **flexible wire** is fed into the aneurysm using a **catheter**. The wire **coils up** inside the aneurysm and seals it up from the **artery**. However, it isn't as effective as surgical clipping in **preventing** another aneurysm from potentially occurring.<sub>7</sub>



These solutions are used when the aneurysm does not need to be removed. However, in instances where the aneurysm must be removed due to the danger of a rupture, this can often **change the shape of the vasal wall** and can alter the optimal blood pressure in that region due to more/less cross-sectional area compared to the **force of the blood flow**.



# Graft & Grow

## ABOUT US:

**Noah:** Data Research and Citations  
**Rayyan:** Website Creator and Study Designer  
**Xander:** Product Engineer and CAD Renders  
**Krish:** Editor, Surgical Research and Review  
**Samay:** Poster Design, Illustrations and Concept

All illustrations are created by our team.  
 We are Year 10 biology and engineering enthusiasts from Merchant Taylors' School, Northwood

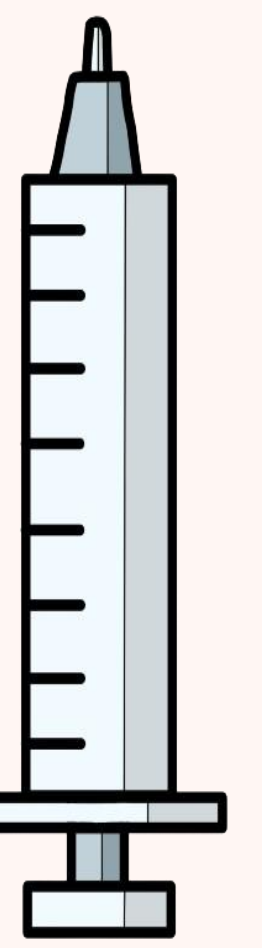


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## Implementation

### Preparation

It will be ensured that the anatomical data of the graft is compatible with the patient; therefore, a **CT scan** will be performed before converting the imaging data into a 3D scan. **CAD software** will be used to construct the graft, facilitating the specific details required by each patient using a **custom approach**. To prepare for the surgery, appropriate **anaesthesia** will be induced.



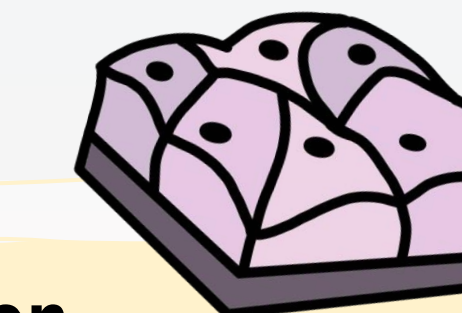
### Using Vascular Bypass Surgery

The **surgeon** will be given the role of determining whether local or general anaesthesia is appropriate based on the scale of the incision. After the incision has been performed to provide access to the affected blood vessel, the vasal walls of the blood vessel will be cut so that the graft can be placed **in between the smooth muscle and endothelium**. To ensure careful positioning of the graft and reduce patient risk, imaging guiding will be used for precise placement. The patient will be made to stay in hospital for **seven days** to recover, before being regularly tested monthly for any **complications** with the integration or decomposition of the graft.

## How It Works

Based on our research we decided to design a **3D printed graft** which could fit within a vasal wall between the **muscle** and the **endothelium**. This would be applicable to both arteries and veins. Our graft will be used to **replace** removed aneurysms which have deformed the vasal wall from its original shape and will be **manufactured flexibly** to ensure that there are no blockages during vasodilation and vasoconstriction.

## Our Design and Scientific Research



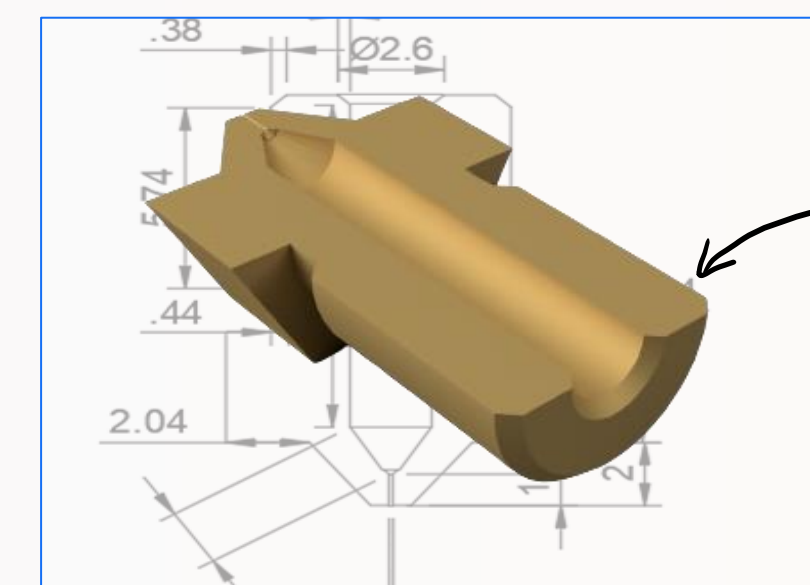
### 3D Printing and Material Science

3D printing uses a **heated nozzle** to melt and extrude **thermoplastic filament**, depositing it in thin layers on a build plate to create complex shapes and geometries. **PLA (polylactic acid)** is an eco-friendly material made from the polymerisation process of lactic acid, a **natural byproduct** of our bodies from **anaerobic respiration**. FDM 3D printing is extremely cost efficient with small parts, such as our graft, each costing less than £0.50. The CT scans are priced at around £450 for private healthcare, however, for the NHS, this procedure would be free.

### Graft Placement and Decomposition

The grafts will replace the inflamed blood vasal wall and the body's natural enzymes (produced in the **lysosomes** of cells) will eventually break the polylactic acid-based grafts into lactic acid, which is either oxidised into **carbon dioxide and water**, or converted and stored as **glycogen in the liver**. A newly grown tissue integrates into the adjacent blood vessels via the channels which provide conditions for **new tissue to develop**. The slow release of lactic acid due to the decomposition of the PLA from our graft would allow for its **easy removal** from the bloodstream.

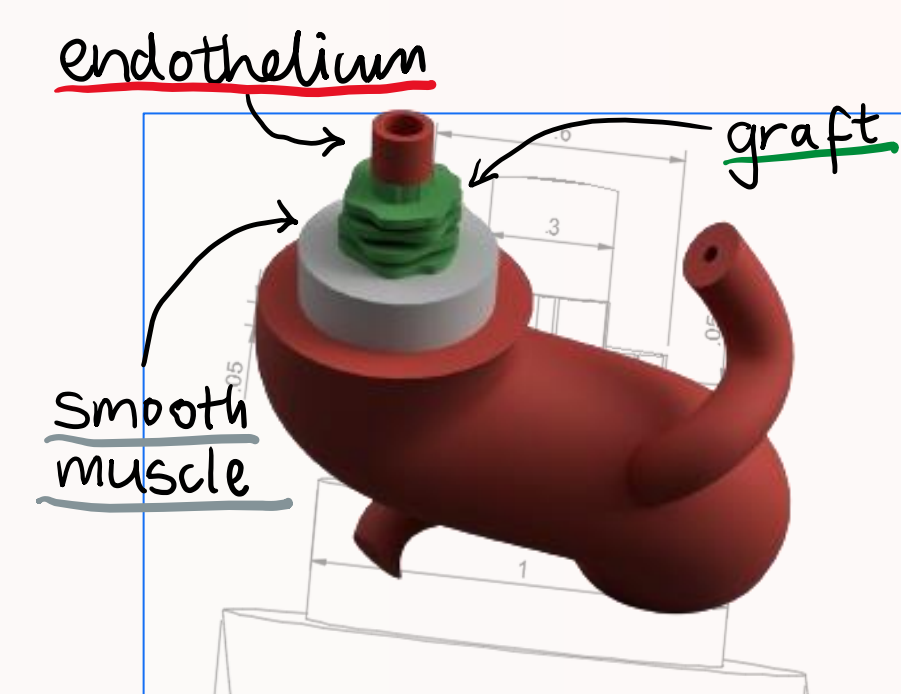
### OUR MODEL OF A 3D PRINTER NOZZLE



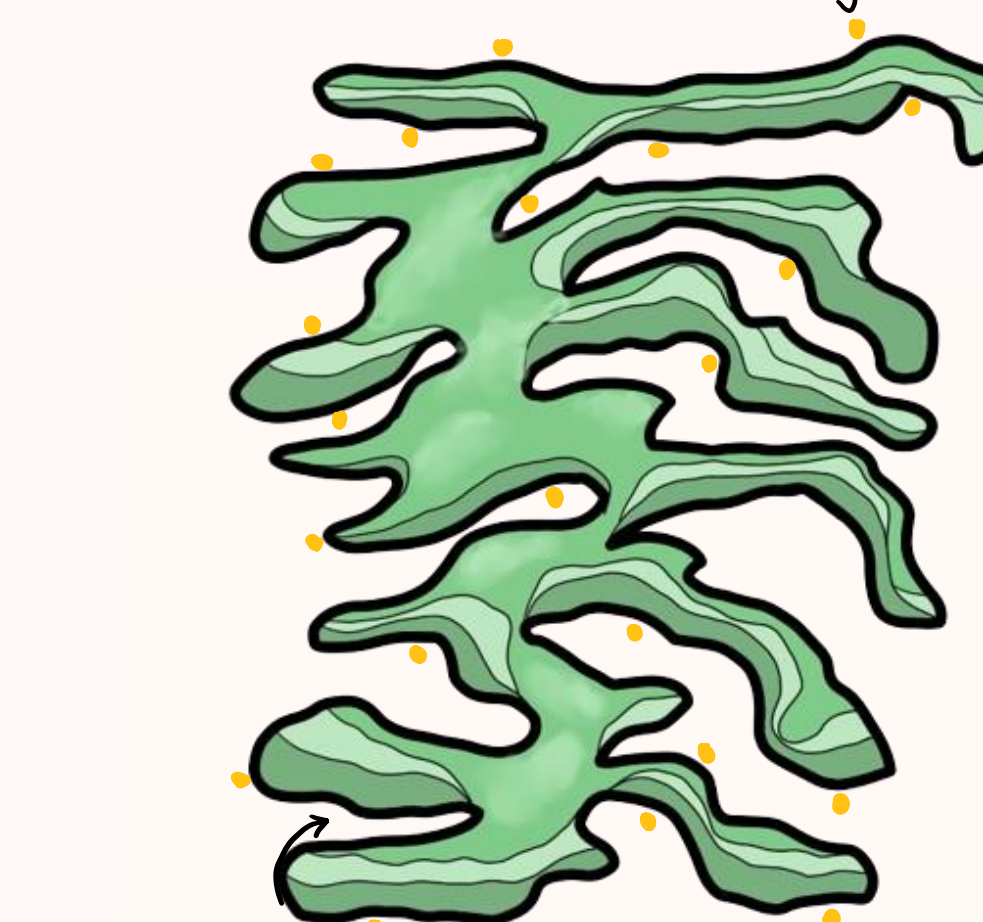
This nozzle is specifically designed to extrude PLA as thin as 0.05mm in diameter

### OUR GRAFT IN A BLOOD VESSEL

This is a cross-section diagram of the graft installed in a fusiform aneurysm



### nutrient capsules (in yellow)



crevices to store nutrients for cell growth stimulation. The crevices also allow for the graft to be flexible, withstanding vasodilation, vasoconstriction and changes to vessel diameter

layer height: 0.1mm  
tolerance: ± 0.05mm

These grafts will be loaded with **proteins** such as growth factor FGF and enzymes to **encourage growth** of new cells and repair of damaged cells. Vitamin C will be present for **collagen synthesis** and vitamin B for cell **metabolism**. These nutrients will be present within the **crevices of the graft** - which provide an additional benefit of **increasing the surface area** to attach these nutrients onto.

### Hydrogels and Anti-Inflammatory Agents

The grafts will be coated in an **amorphous hydrogel** which will act as a barrier to prevent small fragments from breaking off during **biodegradation**, thereby blocking the blood vessels and causing further complications. The hydrogel will provide the grafts with a **smooth surface finish** which replicates the nature of the **endothelium**, serving very similarly to **human blood vessels**. We have selected **biocompatible** materials, a precautionary step against the patient's body rejecting the graft. However, it is still important to address the risk of unwanted inflammation. We would include the chemical **dexamethasone**, which would temporarily reduce the activity of the **white-blood cells** surrounding the affected area. There is little chance of contamination as the area and surgery is already fully sterile. The chances of this side-effect would be **reduced** through this addition. All

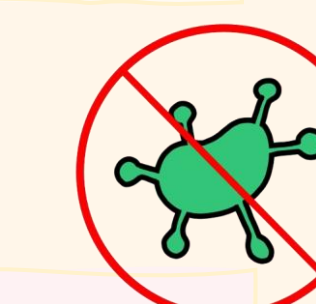
## Limitations

FDM 3D printing is **powerful** and **flexible** but has major limitations. We are using a custom nozzle to have access to 0.1mm nozzle diameter, which is not a standard size for 3D printers. This will allow us to print very **small parts**, however this means that there is a **minimum size** for the grafts.

The limitations of 3D printing also limit us to 0.5mm layer heights. Another limitation is that our solution is **contraindicated** in liver disease as the liver will not be able to transfer and store the lactic acid from the graft.

## Ethics and Safety

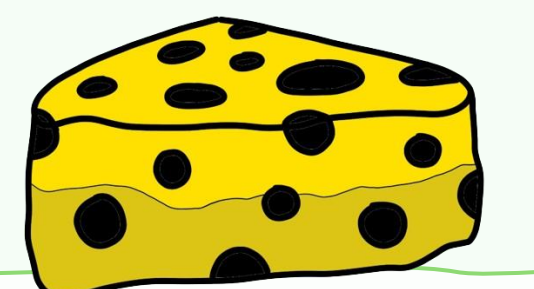
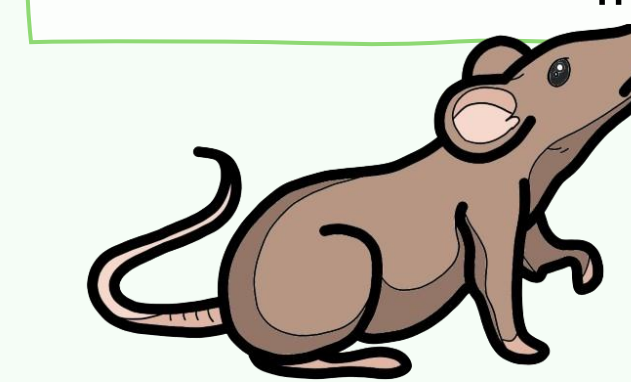
The surgery would be **invasive**, however to ensure safety there would be monitored sterilisation procedures in place for **all equipment** used. **Ultrasonic cleaners** will be used first, then either autoclaving or hydrogen-peroxide plasma sterilisation will be used during this process. These tools will be packaged according to **medical standards** until use. The mice will be **ethically sourced** and we will have informed consent based on the effects on the mice before even shifting to **human testing**. All procedures carried out will comply to the Animals Scientific Procedures Act 1986.



## Cohort Study

We are using mice for our cohort study as they are 95% genetically similar to humans and are easy to source. The same species will be used and their environmental conditions from birth will be the same for all mice.

We will use an **initial cohort** of 30 deceased mice (maximum 24 hours after death to ensure tissue integrity). We will divide the group into two (15 in each): a **test arm** and a **control arm**. The mice will have a section of their endothelium and muscle removed from an artery in the **same location**. The graft will be inserted in the test group whereas the control group will have no graft inserted. A **synthetic perfusion system** will be used to demonstrate blood circulation through the mice - this will **mimic physiological conditions**. A micro-CT scan will confirm the placement of the graft and ensure there are **no potential leaks** from the surgery.



We will be **measuring** the breakdown product(s) (lactic acid) from the PLA after a period of **4 months**, with regular **micro-CT scanning** in place weekly to monitor the growth of the cells around the graft. The period of **degradation** of the graft will be measured as the blood-like solution is pumped through at a **steady rate**. The structure of the grafts will be closely monitored to see if they provide any **additional risk** to the artery.

To **expand** the study, we would increase the **cohort size** to 100 for a more **reliable** study. We would also use industry standard data management systems to handle **large datasets** such as REDcap to store and **analyse** data from large trials, especially if we move from mice to **human clients** based on the safety and effectiveness of the previous cohort study(ies).