Based on research, the fourth finger mainly follows the movement of the fingers next to it. Its main function is for support. Having looked into different sensors and ways to make the finger move, I decided to use a flex sensor attached to a glove on the third finger. This will then control the motor of the prosthetic so that the two fingers move together, with the fourth finger copying the movement of the third. Due to the complex shape of the stump, I decided to attach the prosthetic with a glove instead of by snug fit which professionals use to attach a finger to the hand. I used Fusion 360 CAD to model the finger parts to be printed (F1). They are life-size and based on the dimensions of his other third finger. The finger is split into 3 parts and 2 joints with a motor in the larger joint. As the smaller joint is mainly for support, I designed to be slightly bent at 120° at rest. Elastics will cause it to unbend when holding something and the two parts are attached by a rod (F2)

I independently researched into methods of controlling the prosthetics through different electrical components and techniques. After coding and producing the project using different motors, I found that the servo would be the most efficient.

Articles I have read for research:
Kim, YG., Song, JH., Hong, S. *et al.* Piezoelectric strain sensor with high sensitivity and high stretchability based on kirigami design cutting. *npj Flex Electron* **6**, 52 (2022). https://doi.org/10.1038/s41528-022-00186-4

Lee, KT., Chee, PS., Lim, EH., Kam YH., *et al*. Development of flexible glove sensors for virtual reality (VR) applications (2023). https://www.sciencedirect.com/science/article/abs/pii/S2214785323023246

And other online resources.

Also take into account the fact that the stump can move on its own, so the movement of the whole finger should be offset by the movement of the stump too.

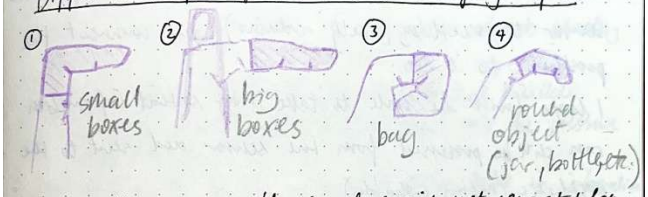
→ the main purpose of the ring finger is for support and strength; doesn't do much on its own; mostly just stuck to the middle finger.
Needed for carrying or holding things.

After asking him, he said that the times when the loss of this finger affect him the most is:

- Carrying things → heavy boxes, shopping bags (generally anything that requires using large forces with the left hand)
- Typing — however, after so many years he has also been able to change how he types to use the other fingers instead, so a prosthetic is not as necessary to help with this specifically.
- Holding things — may fall out because of the gap in the hand.

∴ Focus more on helping carry things for support and strength.
(Typing is not a big problem, and a gap in the hand is therefore automatically fixed with the presence of a prosthetic finger).

Different shapes of hand when carrying objects.



In all these cases, the ring finger is not separated from the fingers next to it, doing simply what they are doing, even if they are not touching each other (if the fingers are splayed).
I also think it would be difficult to make a finger in the shape for number ① (as this is difficult to do even naturally) without code.

06·10·24.

Things that ~~detect~~ can help me detect the movement of the adjacent fingers.

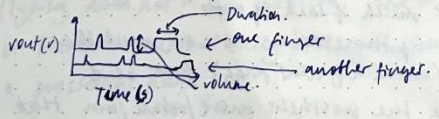
- Look up VR gloves
- Motion capture.
- ~~various~~ Strain sensors (on the outside of the knuckles)
- pressure sensors. (on the inside of the knuckles).

Strain sensors can be used in VR haptic gloves.
→ I could ~~try to~~ have the strain/pressure sensors detect how much of each of those.
The match up those values to how much the knuckles (or the adjacent fingers) have bent.
Then make the prosthetic move/rotate/turn that much.

- However, I would need to connect both the strain/pressure sensor to something (likely arduino), and connect the prosthetic to it too.
I hope I will be able to take it off so that information can still be processed from the sensor and sent to the prosthetic (motors probably).
- Otherwise, it would be very big and clunky and it would be difficult for it to actually be used in day-to-day life (the arduino would be constantly attached to it).
- I would want to figure out a way to connect them (like from Bluetooth or something like that etc.).

07·10·24.

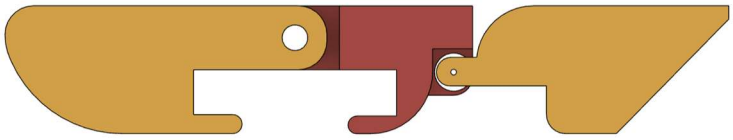
- I also need to figure out how to make the prosthetic (likely small motors) move at the right speed, from taking only information from the sensor. I think this should be possible.
- Piezoelectric strain sensor.
  - used in VR haptic gloves.
  - Reading article "Piezoelectric strain sensor with high sensitivity and high stretchability based on kirigami design cutting".
  - want a sensor with high sensitivity for more accurate movement.
  - can get an output that looks like:



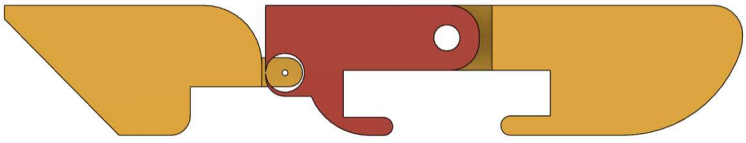
  - could use this to ~~find and~~ control movement of the prosthetic

Some research notes on components

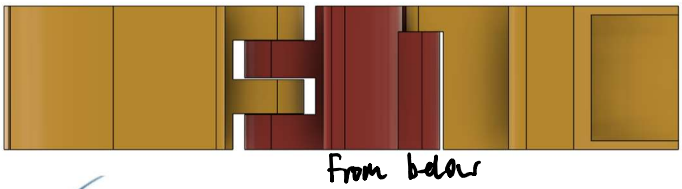
Images of my 3D modelled finger, made of 3 parts. Both joints will be able to bend, rotating the joints with motors, rods and elastics. Designed using CAD on Fusion 360.



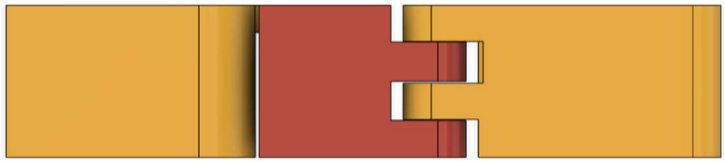
From left



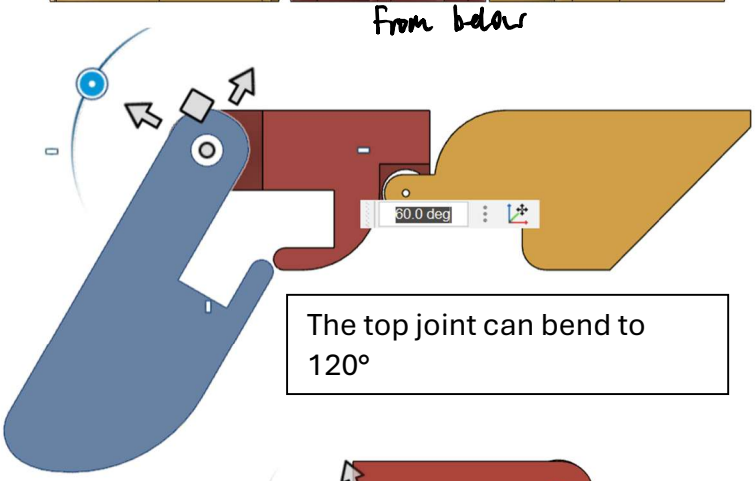
From right



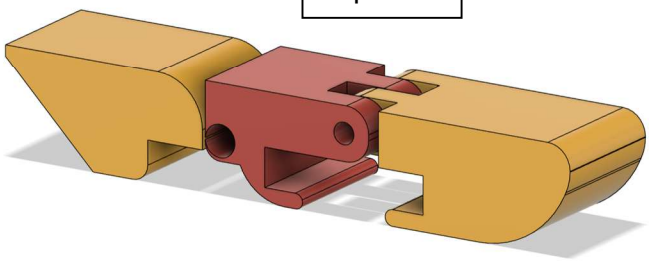
From below

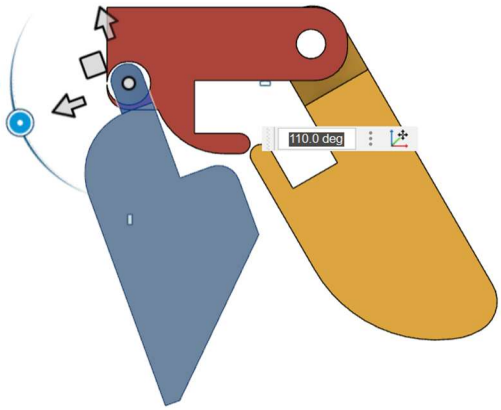


Top view

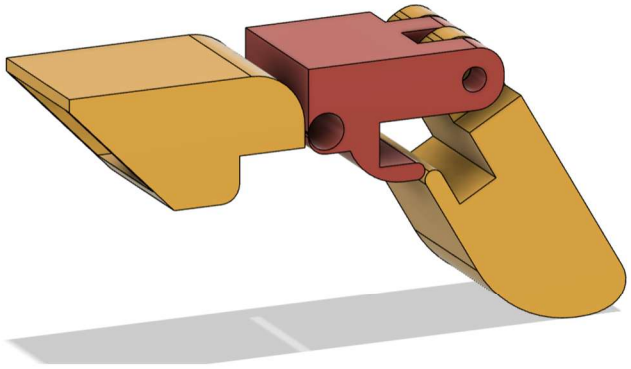


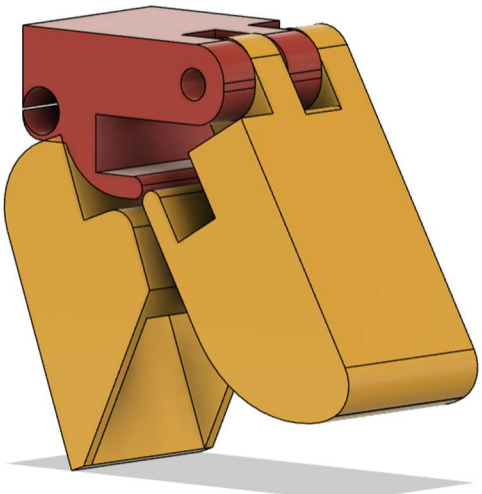
The top joint can bend to 120°

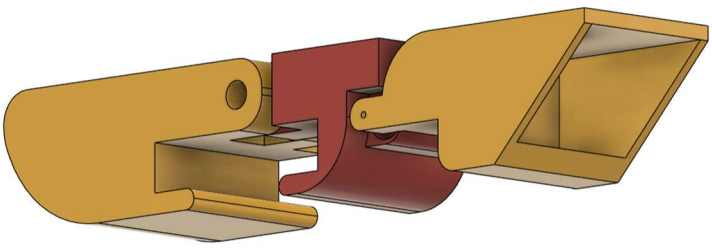


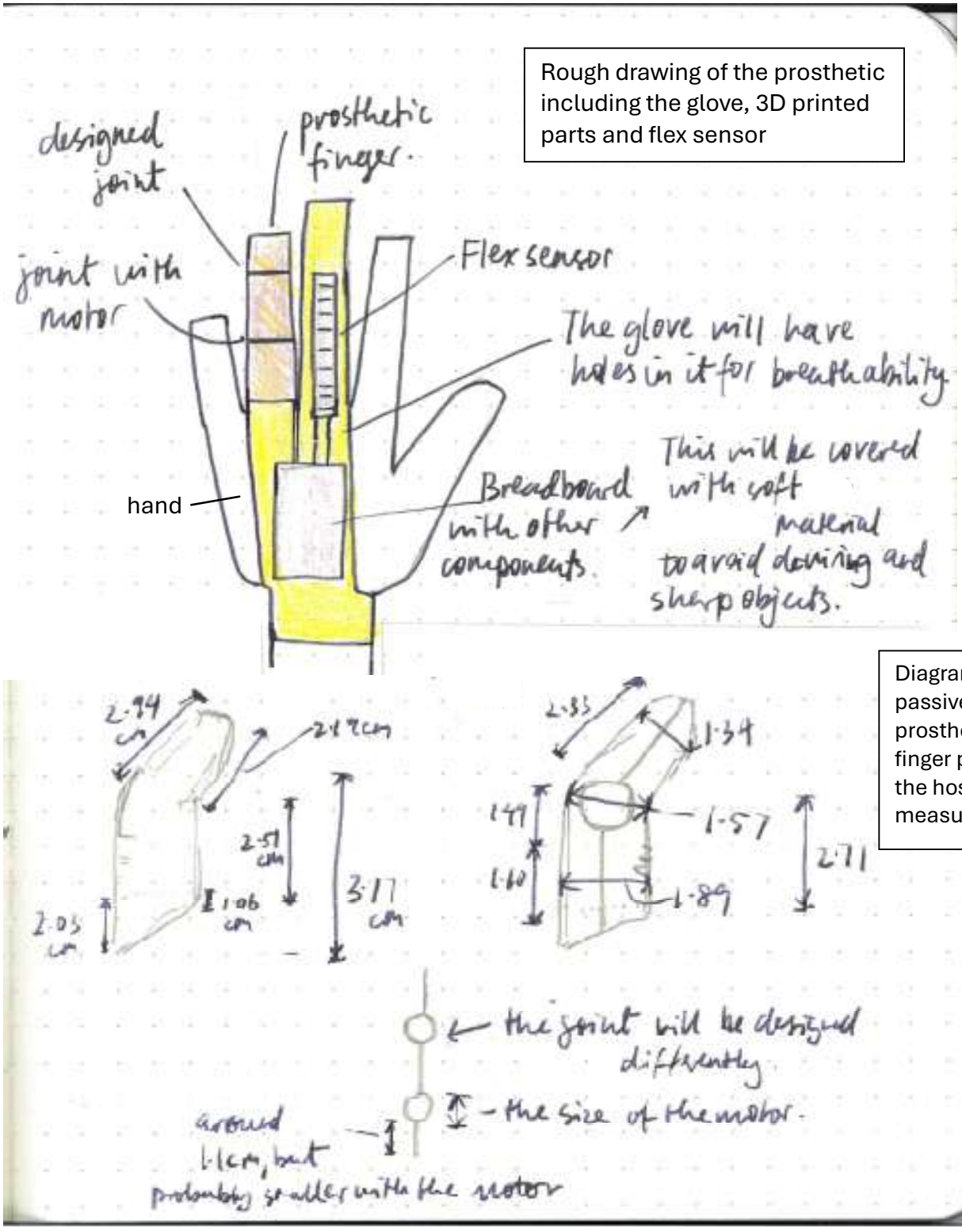


The bottom joint with the motor can bent do smallest 70°



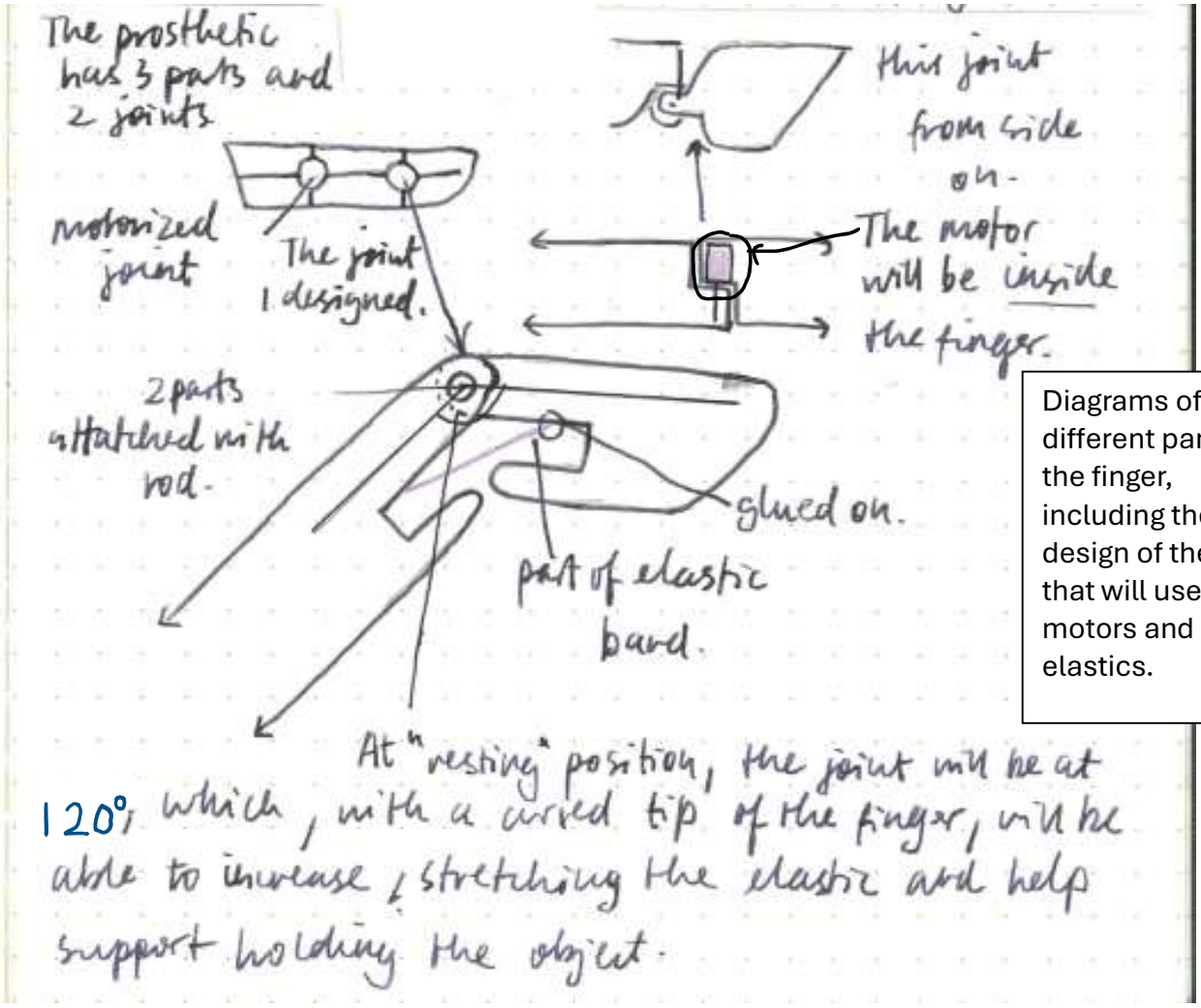






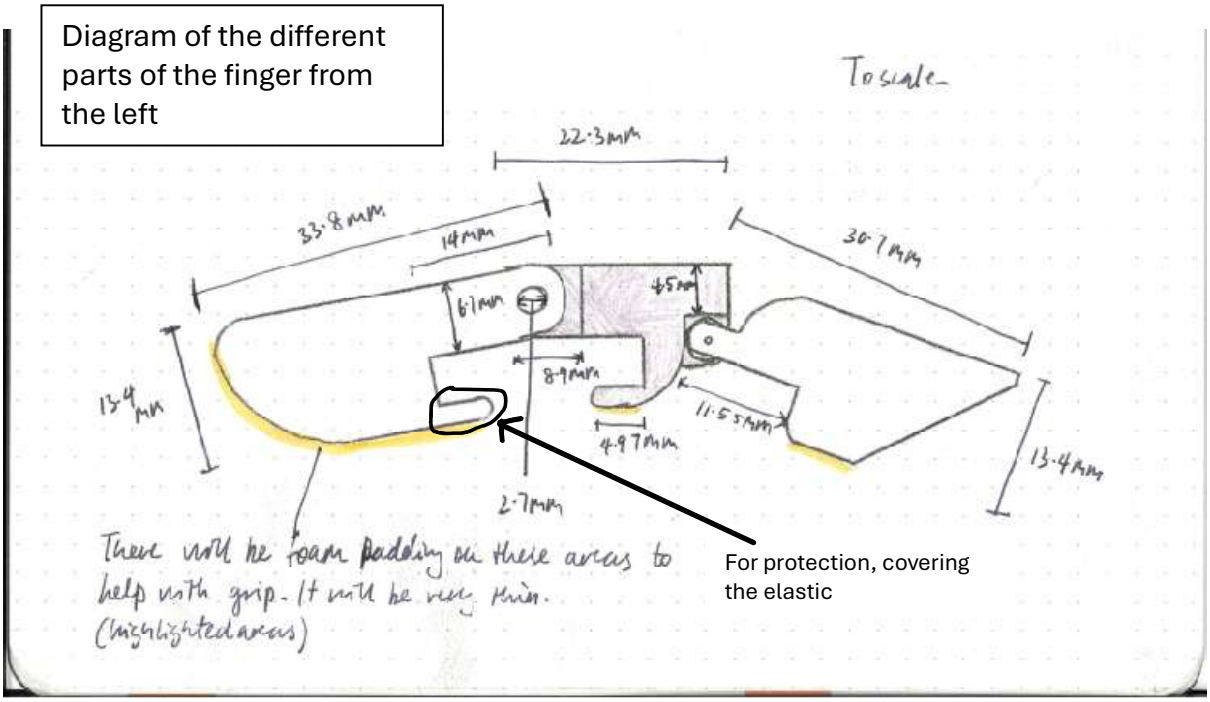
Rough drawing of the prosthetic including the glove, 3D printed parts and flex sensor

Diagram of the passive prosthetic of the finger provided by the hospital, for measurements.



Diagrams of the different parts of the finger, including the design of the joints that will use both motors and elastics.

Diagram of the different parts of the finger from the left



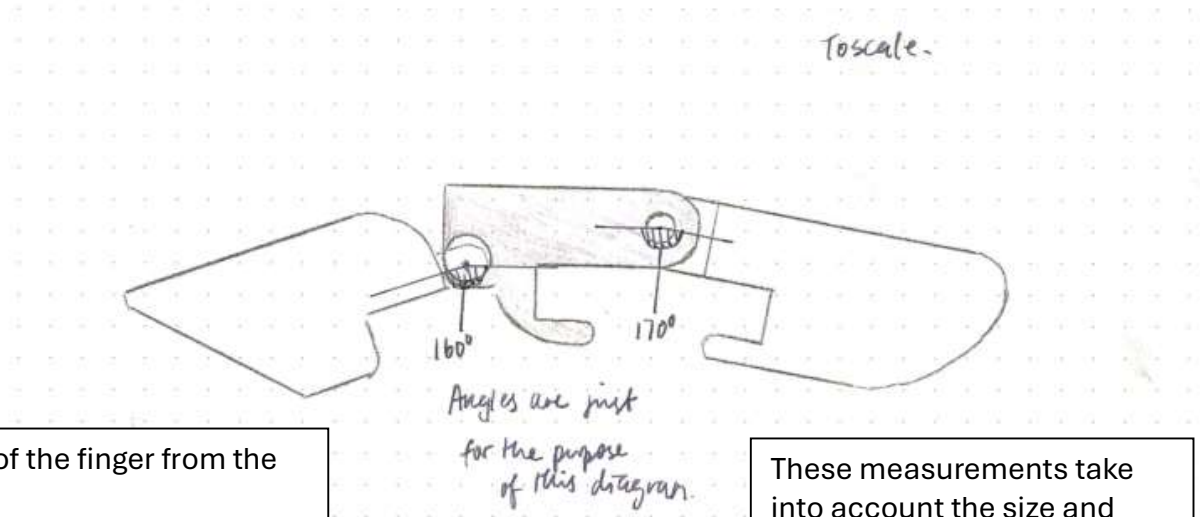


Diagram of the finger from the right.

These measurements take into account the size and shape of the rod, how the real finger would be, the stump, and the DC motor which I had. Both the size and shape will be modified when I have a stepper motor of appropriate size, which will replace the DC motor.

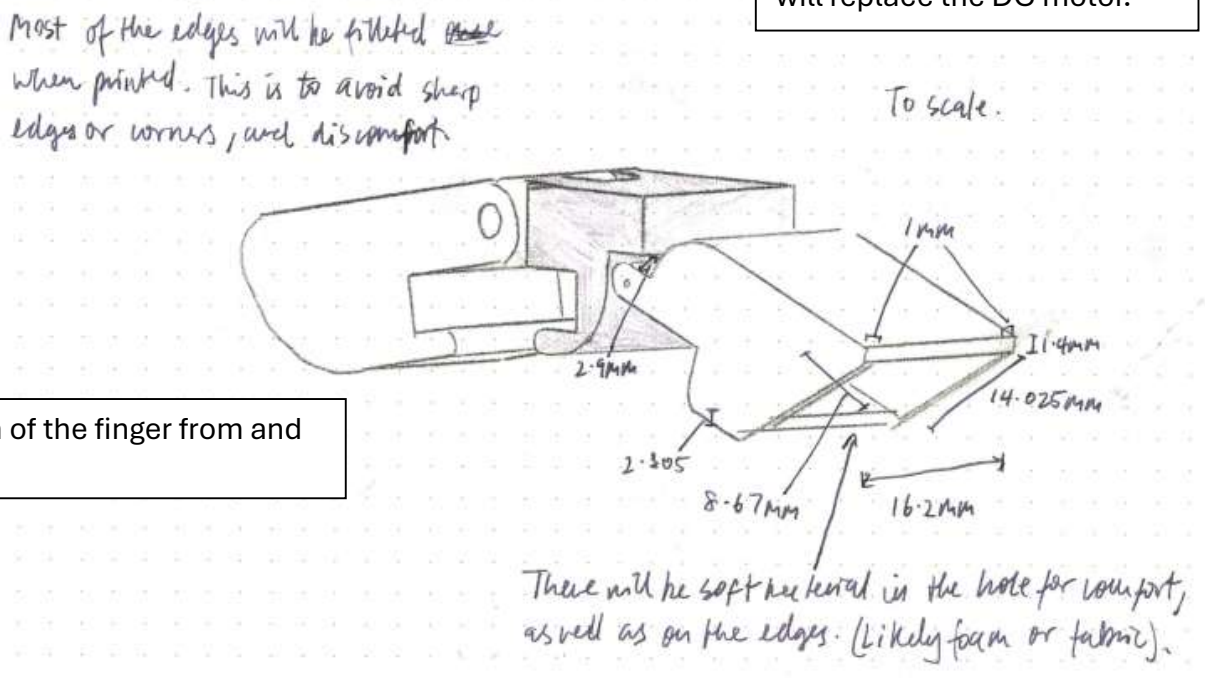


Diagram of the finger from and angle.

I would love to be able to attatch the prosthetic with snug fit which is used by professionals, using biocompatible materials such as titanium alloy or hydroxyapatite coated materials. Certain electronic components could be reduced in size to fit inside the finger parts. I could also have the prosthetic implanted into the finger, though the way the finger is controlled may have to change (possibly using biological inputs instead of an attatched flex sensor).

```ino
#include <Servo.h>
Servo myservo;
const int flexSensor = A0;
void setup() {
  myservo.attach(9);
  Serial.begin(9600);
}
void loop() {
  int flexVal = analogRead(flexSensor);  // Reads the flex sensor
  Serial.println(flexVal);               // Prints the flex sensor value
  // Maps the flex sensor for the range of the servo: 0 to 180 degrees
  int servoPosition = map(flexVal, 0, 1023, 0, 180);

  myservo.write(servoPosition);  // moves the servo to the position
  delay(15);
}
```

Working servo code for the servo circuit, with a flex sensor

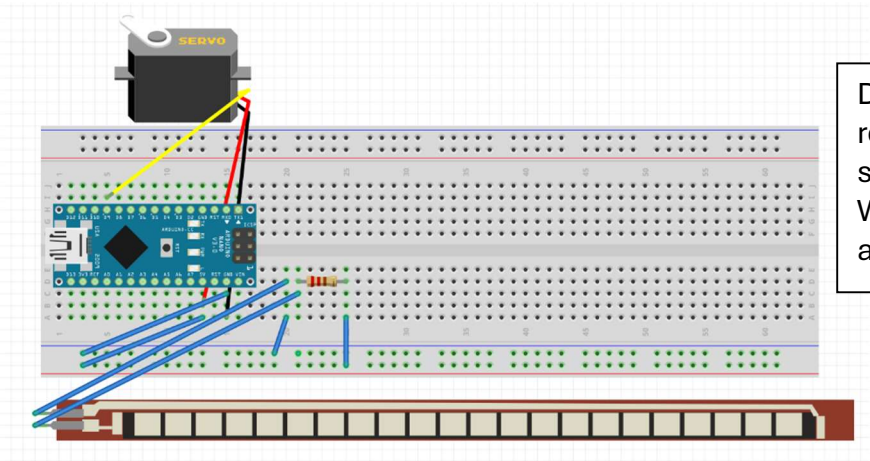
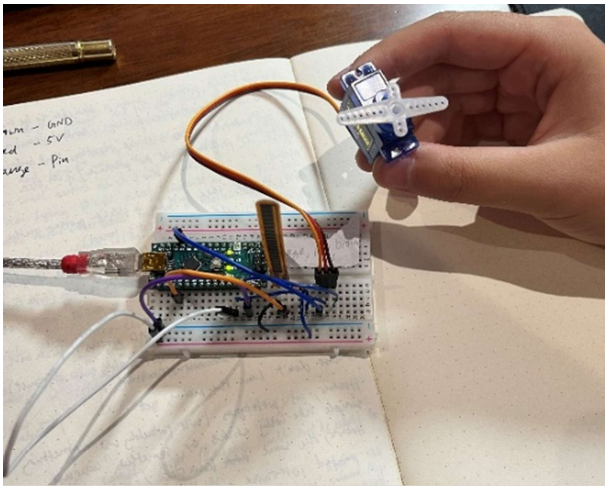
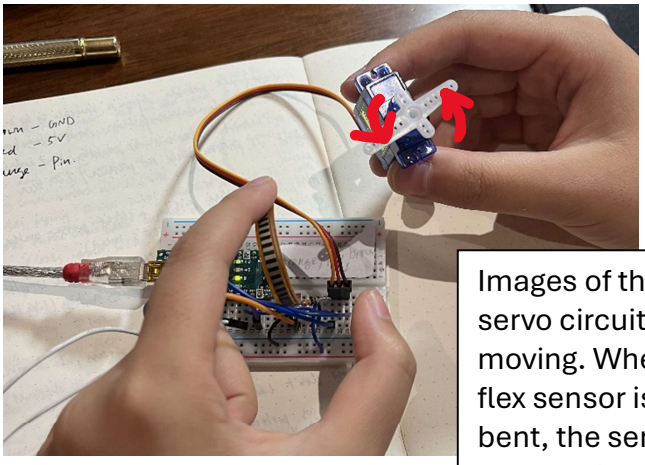


Diagram of servo circuit, including 10k resistor, Arduino Nano, flex sensor, and servo motor.
With the code above, the servo rotates as the flex sensor is bent.



Sensor not bent – servo at default position



Sensor bent – servo has rotated

Images of the servo circuit moving. When the flex sensor is bent, the servo moves – but only within its range (quite small)