Glucolite

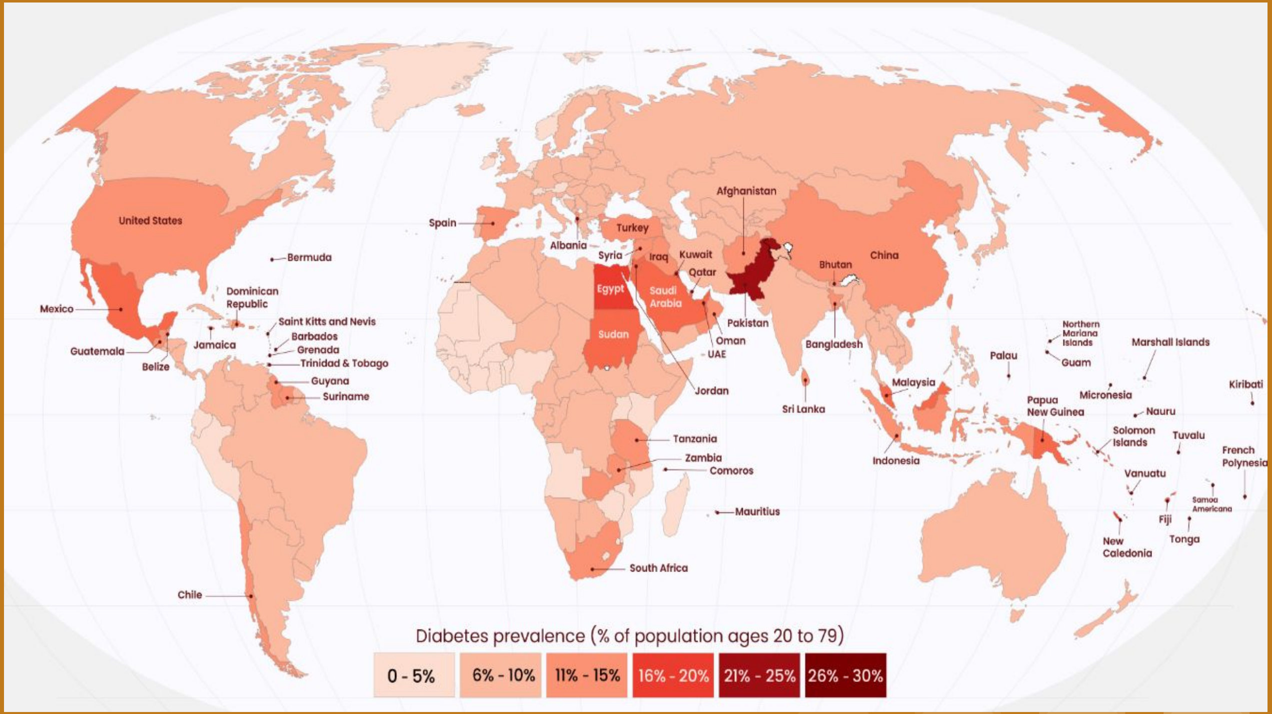
Cost Effective, App Based Biosensor for Diabetes management

Ishani Sanyal

Diabetes is one of the leading causes of death

About <u>537 million adults</u> (20 - 79 yrs) worldwide have diabetes.

<u>1.5 million deaths</u> are directly attributed to diabetes each year!



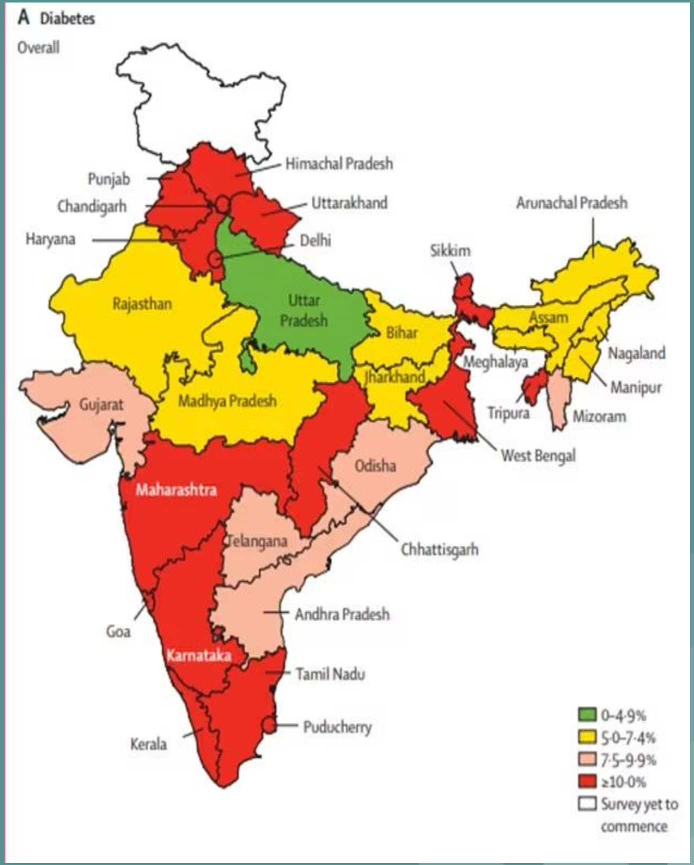
[What is a biosensor>>>>](#)

India: Diabetes capital of the world!

- **101 million people (11.4%) - diabetics**

- **136 million people (15.3%) - pre-diabetic**

- ***17% of the global diabetes population!***

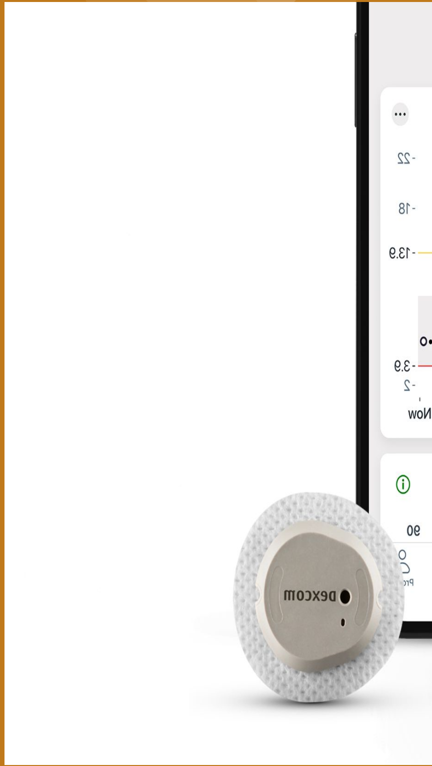


There are various Glucose monitoring devices in the market

- Accu-Check: **₹960 +** monthly**(₹926 + ₹589)**
- BeatO Smart**: ₹744 +** monthly**(₹544)**
- DR. MOREPEN GlucoOne**: ₹665 +** monthly**(₹636 + ₹149)**

The current CGM market is dominated by;

- Abbott Diabetes Care Inc (Freestyle Libre) **-₹5,000+/2 weeks**
- Dexcom Inc. : **₹6,000+/10 days**
- Medtronic PLC : **₹50,000+ annually**



Cost of CGM sensors are a barrier: Too Expensive!

- **extremely expensive** and not within the reach of the average indian family

- They remain **invasive** in nature

- Those less expensive are **not continuous monitoring systems**

To Address that,my solution looks at;

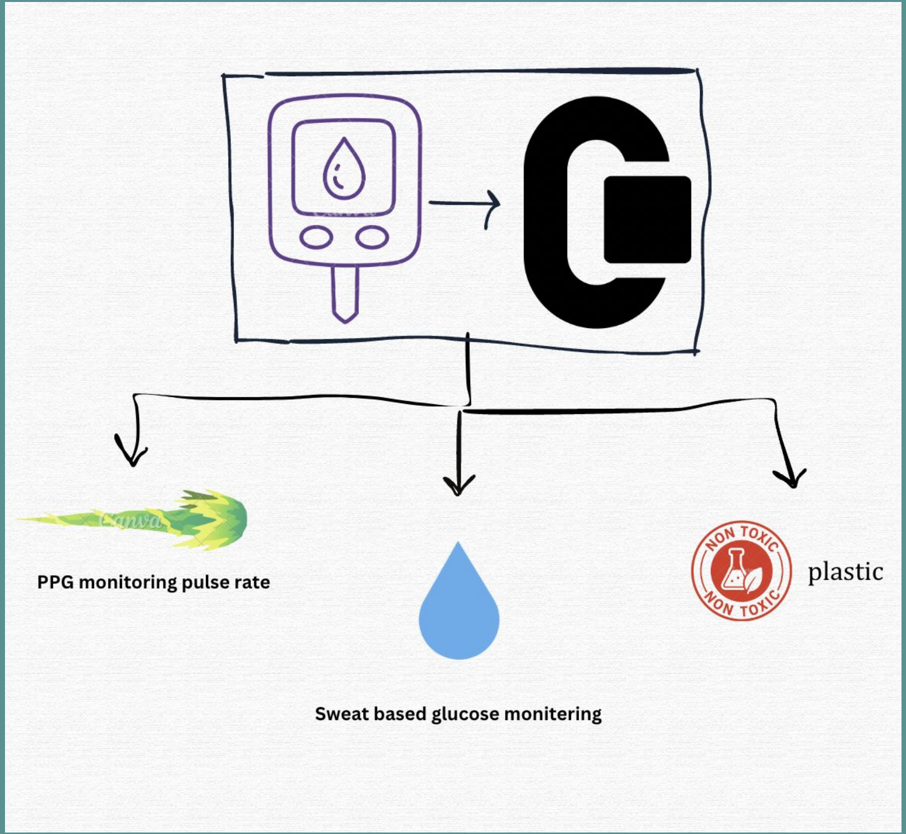
Building a biosensor that is;

1. Reliable, Low Cost, Non Invasive and Continuously monitoring
2. *Uses a data analysis app to analyse the data from the biosensor for accuracy and add additional parameters to finds trends*

Reliable, Low Cost, Non Invasive and Continuously monitoring...

- Using a **Photoplethysmography (ppg)** based optical technique

- supplemented by **enzyme monitoring tools to measure sweat**

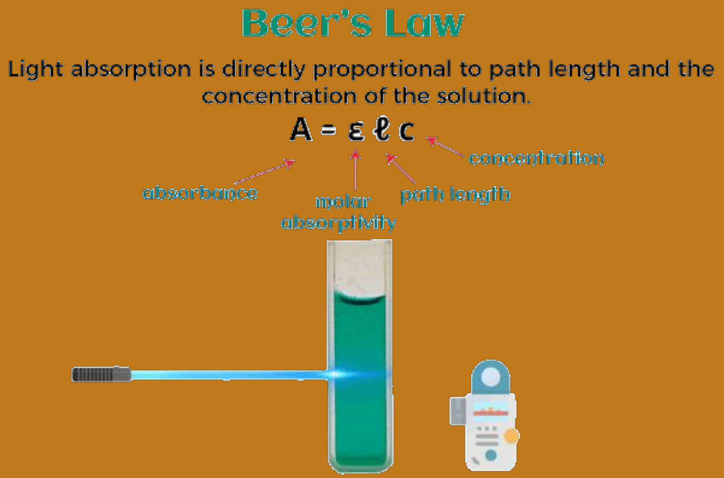


Principle of the infra-red Photoplesmography

Beer-Lambert Law

1. the more the number of particles that absorb light of a specific monochromatic wavelength the greater the extent of absorption of the radiation

2. Using this we can detect glucose by:
   a. Identifying the frequency of wavelength that glucose absorbs but is limitedly absorbed by other particles like RBC's, WBC's and other plasma proteins.
   b. Keep the distance constant through the use of a wearable device
   c. Use the lightwave at a certain concentration and measure the amount absorbed by subtracting the final concentration of emitted light to the total.
   d. Use a behind the scenes algorithm to further process this information
      i. Further evidence of ongoing research on this slide



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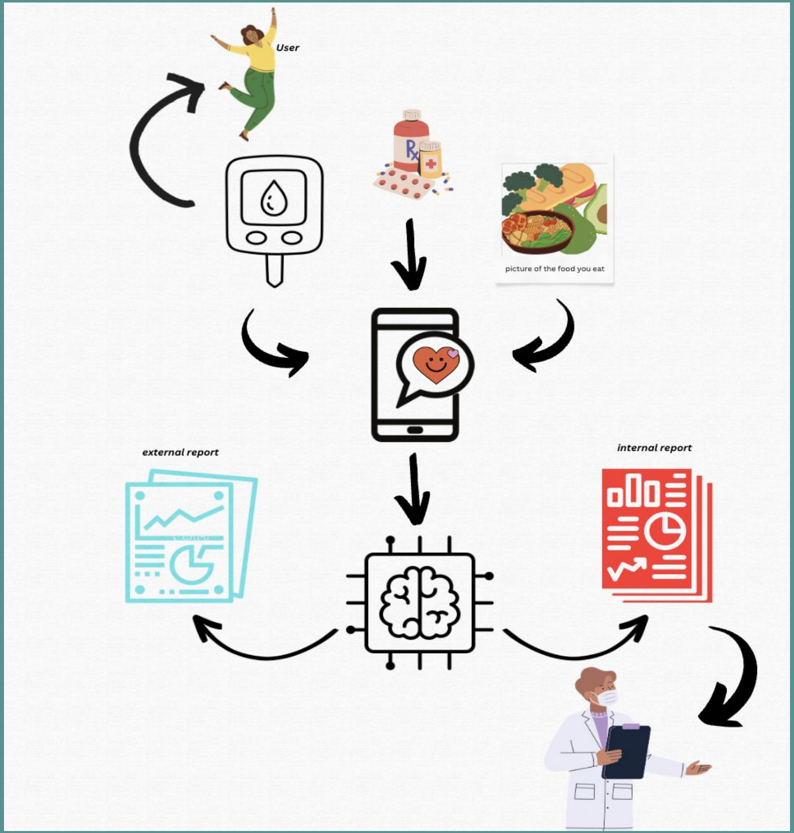
data analysis app to accompany the sensor

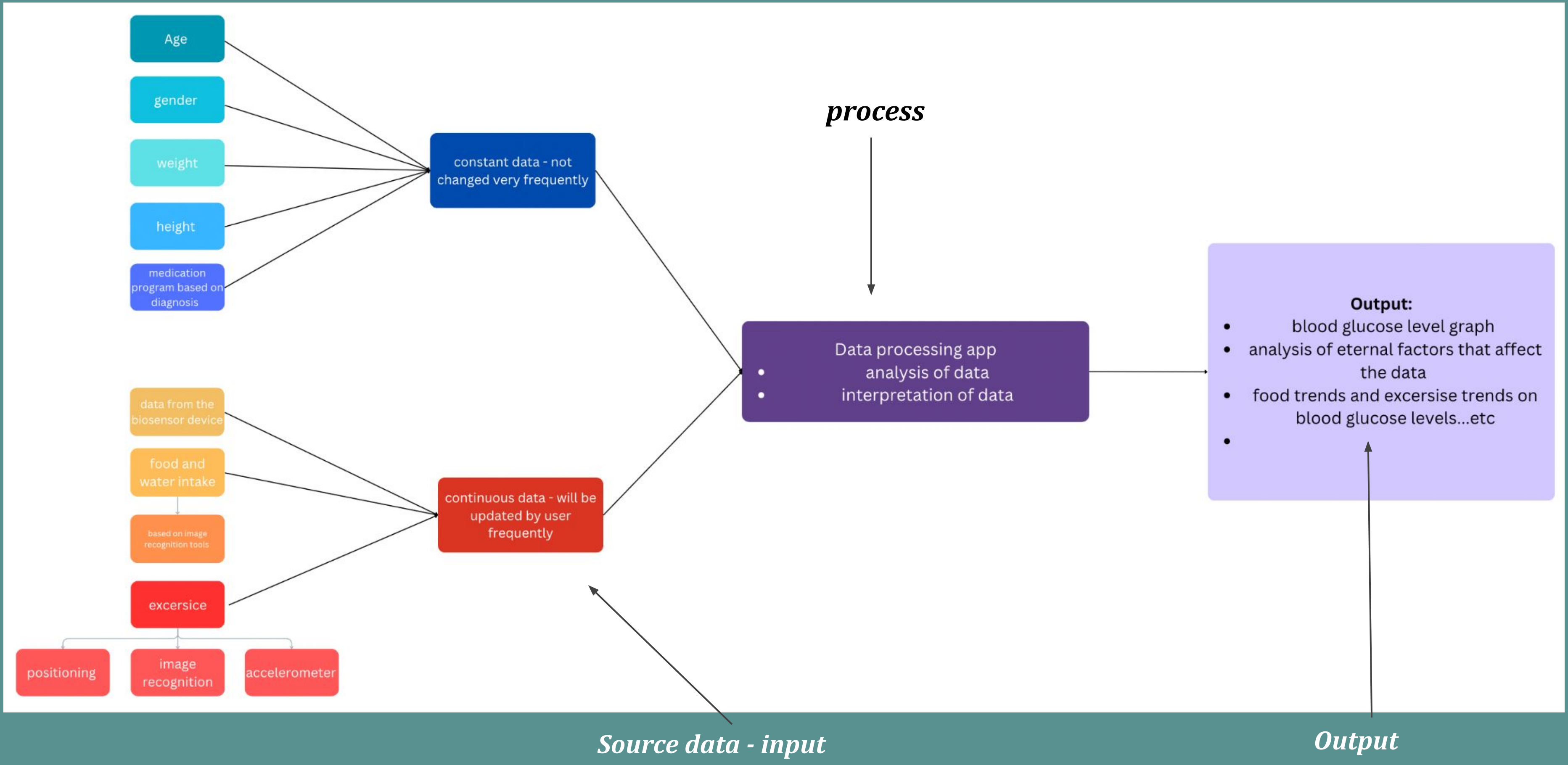
- **Implementation of AI analysis** of biosensor data

- Addition of external parameters for identification of trends

- The user **inputs various parameters** such as;
    - Constant data;
    - Continuous data;



Functional architecture of data model



Processing of the PPG signal

There are open source codes that can be used to help in the processing of the ppg.

ppg-signal-extraction

Extraction of photoplethysmogram (PPG) signal from camera recording and assessment of PPG signal quality

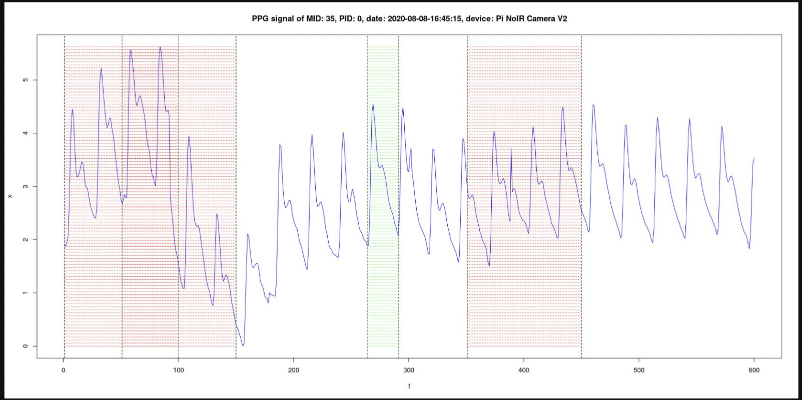


Figure 1: Example of extracted PPG signal (the good part of the signal is colored in green)

Description

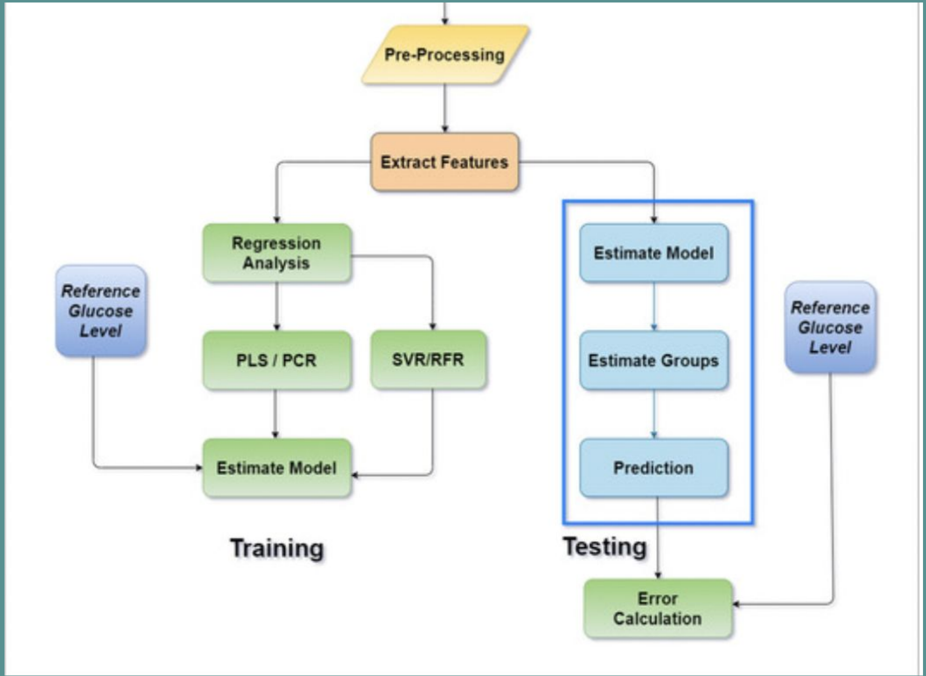
To capture PPG signal from a camera, you can try using the Python or Bash scripts in `scripts` directory:

- `capture-noir.py` - extracts frames from video captured by Raspberry Pi device using the camera without infrared filter;
- `convert-iphone.sh` - uses `ffmpeg` to extract frames from video captured by iPhone camera (video in QTFF format);
- `save-measurement.py` - extracts the PPG signal from provided video frames (images in PNG format) and saves the signal to a CSV file;

How the General AI based algorithm will work

Input of physiological parameters

Calibration of the ppg monitoring device - with parameters including blood sugar, heart rate and wrist size



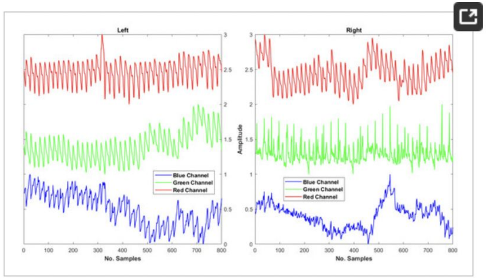


Figure 3. Representative PPG signal extracted from the (Red) channel, (Green) channel, and (Blue) channel of two video frames of varying quality. The extracted PPG on the left side signal was observed to be more reliable compared to the right side.

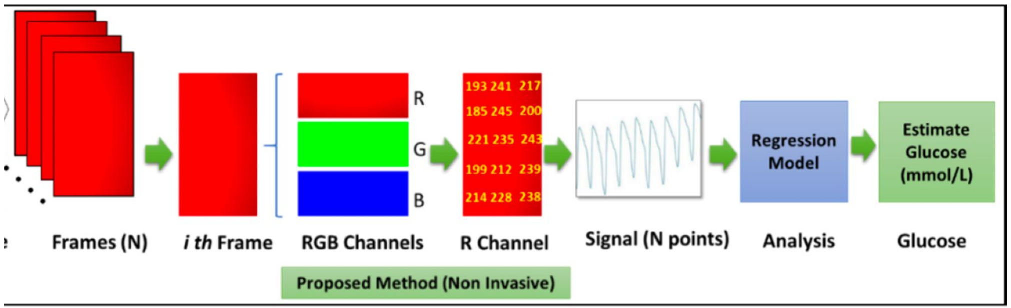


image recognition for food…

Using open source codes, we can implement a camera based food tracker that uses AI to generate the nutritional value of food.

pixels_per_inch_sq= *plate_pixels_area / actual_plate_area*

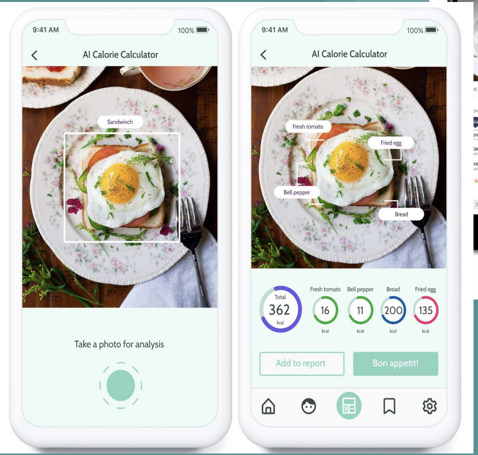
real_food_area = *masked_food_pixel_area / pixels_per_inch_sq*

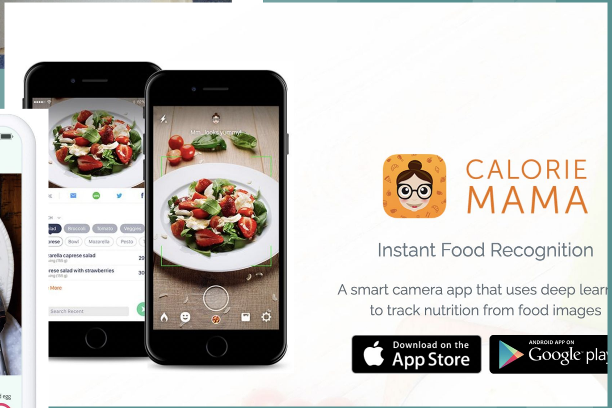
Get camera input

This mobile application gets the camera input using the functions defined in the file `CameraActivity.java`. Th
`AndroidManifest.xml` to set the camera orientation.

`CameraActivity` also contains code to capture user preferences from the UI and make them available to other methods.

```
model = Model.valueOf(modelSpinner.getSelectedItem().toString().toUpperCase());
device = Device.valueOf(deviceSpinner.getSelectedItem().toString());
numThreads = Integer.parseInt(threadsTextView.getText().toString().trim());
```





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Benefits/Promise of my Solution

- **Is a reliable and LOW COST method of sensing blood sugar**
- **Is non invasive, making it safer**
- *Is a long term solution - less waste!*
- More accurate readings due to the AI system
- Identification of trends in daily habits

Appendix slides……

Literary review:

https://whimsical.com/building-a-biosensor-sd2-P8dSADSRJNjK6hyeaZMxPK

https://www.canva.com/design/DAFsF_cO1nA/Eh55FiGWzcWI53R5XEeX-g/edit?utm_content=DAFsF_cO1nA&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4986445/

https://www.thehindu.com/sci-tech/health/31-million-more-indians-became-diabetic-between-2019-2021-says-study/article66949970.ece#:~:text=New%20National%20estimates%20for%20diabetes,351%20million%20had%20abdominal%20obesity.

https://www.mdpi.com/2076-3417/11/2/618

Literary review II

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10057625/#:~:text=Its%20intensity%20is%20reduced%20due,blood%20with%20lower%20glucose%20levels.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9229484/

https://www.sciencedirect.com/science/article/abs/pii/S1746809421003037

https://github.com/markolalovic/ppg-signal-extraction

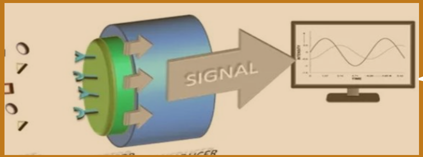
https://www.lftechnology.com/blog/ai/image-calorie-estimation-deep-learning/
https://github.com/Ravi-Teja-konda/trackMyNutrition/blob/master/EXPLORE_THE_CODE.md
https://azati.ai/portfolio/ai-calorie-calculator-and-food-recognition/

What is a biosensor

A biosensor is a device that measures biological or chemical reactions by generating signals proportional to the concentration of an analyte in the reaction.

~ National Library of Medicine: National Center of Biotechnology Information

In simple words, a biosensor is a analytical device that can be used to detect changes in biological processes such as changes in glucose levels, converts them into electronic signals to produce data that can be interpreted and actioned.



- Detection of Diseases
- Detection of Pollutants
- Disease Monitoring
- Drug Discovery

Varied application of Biosensors

In the case of diabetes, biosensors help monitor the blood sugar levels in the body, allowing the management of them

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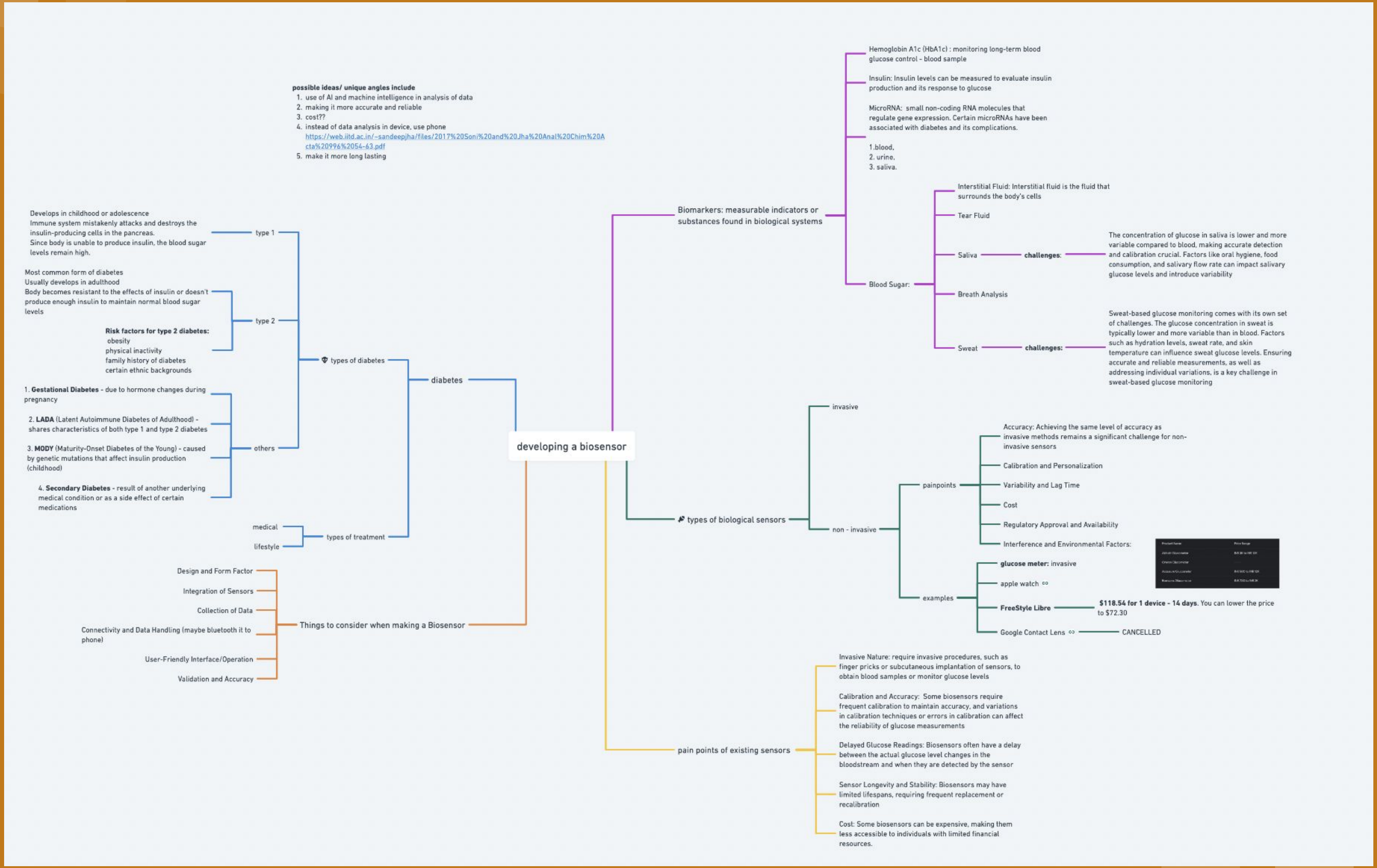
My Keyword Tree



My Angle to the Problem

Unique angle to the problem- Build a biosensor that is;

- Part A: Reliable, Low cost
- Part B: Value add analysis and actionable interpretation of data generated.

Solution 1: Build a new reliable and low cost biosensor and add data analytics capability (Part A + Part B)

Solution 2: Take an existing biosensor and add Part B (data analysis and interpretation)

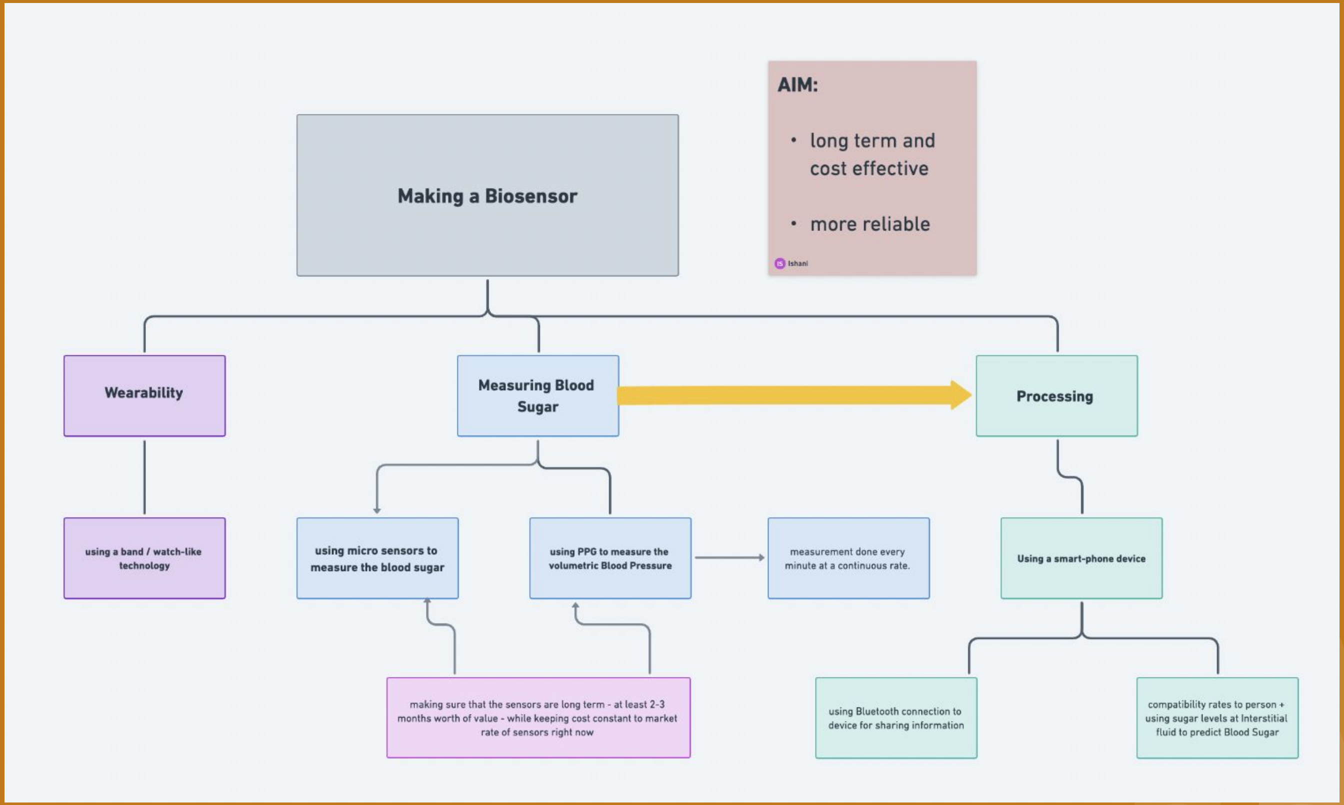
Pros: *Larger population will benefit, affordable.*

Cons: New device will need ***longer time to build*** *as it will need to be* ***tested and approved*** *by Central Drugs Standard Control Organisation (CDSCO)- India, FDA- USA*

Pros*:* ***Quicker to market****, enables diabetics to benefit from data analytics faster*

Cons*: Expensive, Will not reach all sections of population*

System Diagram



Other solutions out there

Freestyle libre 3

Dexcom G7

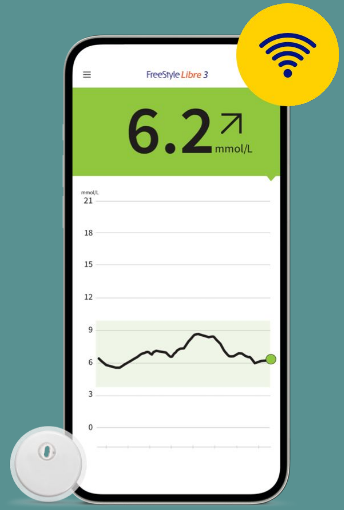
May cause irritation

Results may not be as accurate as a traditional blood calibration system

Doesn't measure the current blood sugar but that of 15 mins before

Is expensive and cannot be bought over the counter top

Sensor must be replaced regularly and can stop working before the given time limit.



Build a wearable biosensor device capable of continuously monitoring glucose levels in individuals with diabetes, enhancing their management of the condition							
PROBLEM	1. SOLUTION APPROACH			2. EVIDENCE FOR WHY SOLUTION CAN WORK		3. My SOLUTION ANGLE: EXTRAPOLATING FROM EVIDENCE	
Problem you are focusing on	**Solution Approach you are taking (From Creative Ideation Tool, Solution evaluator)**	**Goal of Solution**	**Hypothesis/Assumptions you are making**	**That it can be impactful**	**That it is doable**	**How I can make it more impactful**	**How I can make it more doable**
				reducing cost			
Build a wearable biosensor device capable of continuously monitoring glucose levels in individuals with diabetes, enhancing their management of the condition	to create an affordable, reliable and durable biosensor for diabetes monitorring	I want millions of people use my mobile phone/app-based affordable, reliable, durable biosense solution to monitor their blood glucose levels actively to avoid serious health complications as well as manage the quality of their life better	It is possible to predict the possible health consequences through blood sugar	High blood sugar levels are a major risk factor for diabetes complications. Complications of diabetes can affect many parts of the body, including the heart, kidneys, eyes, and nerves. ***There is a strong association between blood sugar levels and the risk of diabetes complications****- for example: A study found that people with type 2 diabetes who had an A1C level of 8% were 2 times more likely to develop heart disease than people with an A1C level of 6%* Evidence shows that controlling blood sugar levels is important for reducing the risk of diabetes complications *link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3134546/* A study found that self-monitoring of blood glucose (SMBG) is **effective in improving glycemic control** in people with type 1 diabetes allowing people to make adjustments to their treatment plan depending on their BS levels. *link : https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4074758/* A study found that blood glucose monitoring is **important for preventing hypoglycemia** in people with diabetes - which can lead to seizures, coma, and even death. Monitoring BS can allow early identification. *link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6248531* .		Therefore, as a result of my research, it is imperitive that the biosensor that I provide needs to be of a lower cost and needs to work for a longer duration. The main barrier to not using CGM devices, despite a study releasing the statistic that more than 90% of users want to use the technology, is the affordability of the device.	
			Smartphone based biosensors are useful	through the monitoring of chronic diseases, smartphones can be used to **track a variety of health metrics**, such as blood glucose levels, heart rate, and respiratory rate. This information can be used to help people **manage their chronic conditions** and prevent complications. For example, A study published in the journal *JAMA Internal Medicine* found that smartphone-based biomonitoring devices can be used to **improve glycemic control** in people with type 2 diabetes.	**Dexcom G6 CGM** : sends the readings to a smartphone app, which can be used to track blood sugar levels and make adjustments to insulin treatment **FreeStyle Libre 2:** the device sends the readings to a smartphone app, which can be used to track blood sugar levels and set alarms for high and low blood sugar levels. **Blucon NightRider 2**: Bluetooth-enabled adapter that can be used with a variety of insulin pumps to send blood glucose readings to a smartphone app		build an app through which all the signal processing from the biosensor can be done. The app must contain the algorithm and data will be given through the sensors bluetooth connection. We can use an AI based algorithm to produce more accurate results. Since all the heavy duty processing will be done through the app, the CGM device must simply contain the bio-sensor, that measures the glucose, and the data trasmitter - which will transmit the results. this will reduce the size of the sensor, therefore lower the cost of the materials required. using open source files and codes can also reduce the production cost of the mechanism
			There are benefits to using CGM devices	According to Dr. Tara Kim, since CGM gives continuous data, you can see '**patterns**', through which we can enable a more '**personalized care**'. Another benefit she mentions are the '**alarms** can be set to avoid significant highs and lows' According to the article continued, other benefits include; overview into **overnight blood sugar** levels, better **outlook on trends**, less finger pricking (invasive methods), fewer emergencies, and sharing of information to healthcare provider *link:https://www.forbes.com/health/conditions/diabetes/continuous-glucose-monitor/* .	A study published in the journal *Diabetes Care* found that Bluetooth-enabled CGM systems were associated with a **lower risk of hypoglycemia** than SMBG systems. The study found that people who used Bluetooth-enabled CGM systems were **30% less likely to experience hypoglycemia** than people who used SMBG systems. Another study published in the journal *Nature Medicine* found that Bluetooth-enabled CGM systems were **associated with a lower risk of diabetic ketoacidosis (DKA**) than SMBG systems. DKA is a serious complication of diabetes that can be fatal. The study found that people who used Bluetooth-enabled CGM systems were **50% less likely to develop DKA** than people who used SMBG systems.	create an alarm signal, for high and low bs levels, like small beeping sounds on phone to alert the user and maybe their family - who will be connect through the app	
			people will want to have a CGM device	Participants in a mixed-method study shared an **overwhelmingly positive reception** and significant interest in continuous glucose monitoring. **90% were familiar** with CGM methods, valuing the regular feedback and better diebets monitoring. However, **83% had not had the opportunity to use CGM devices** as a result of the cost. link:https://www.prnewswire.com/news-releases/one-drop-study-signals-significant-growing-interest-in-continuous-glucose-monitors-cgms-among-people-with-type-2-diabetes-t2d-301561358.html .			
			people want to save money	The cost of CGM devices can **range from $1,000 to $5,000** per year with varied amount of insurance depending on the level of diabetes monitoring required. Furthermore, most of the CGM supplies are also high cost amd must be replaced every 10-14 days. A study, in the journal Diabetes Care, shows that the average cost of CGM is $4,200 which is **more than triple the cost** of traditional glucose monitorring ($1,200) The **barrier of cost** is one of the most problematic reasons for access - especially for people with low income salaries			
			bluetooth is less costly to other method		cost of **bluetooth tech = 1$ vs wifi = 3-5** A study published in the journal *JAMA Internal Medicine* found that Bluetooth-enabled continuous glucose monitoring (CGM) systems were **significantly less costly than traditional fingerstick blood glucose monitoring** (SMBG) systems over a 12-month period. The study found that the average cost of **Bluetooth-enabled CGM systems was $7,337 per year**, while the average **cost of SMBG systems was $10,534 per year**.		

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			Biosensor connected to phone (via bluetooth) is reliable/accurate	A study published in the journal *Nature Medicine* found that a Bluetooth-based biosensor was able to **accurately measure blood glucose** levels in real time. The study found that the biosensor had an **accuracy of 98%**, which is comparable to the accuracy of traditional fingerstick blood glucose meters A study published in the journal *Diabetes Care* found that a Bluetooth-based biosensor was able to **detect hypoglycemia (low blood sugar) with an accuracy of 95%.** The study found that the biosensor was able to **detect hypoglycemia early**, which allowed people to take corrective action early.	**AliveCor Heart Monitor**: This device uses Bluetooth to transmit electrocardiogram (ECG) data from a wearable device to a smartphone or other device **Dexcom G6 CGM**: This device uses Bluetooth to transmit glucose readings from a sensor inserted under the skin to a smartphone or other device.		Do a more personal callibration as opposed to the calibration done through the factory - will provde more reliable results. Furthermore, use a stron bluetooth connection mechanism, so that the data flow is continuous.
			it is possible to extend the longitivity of a biosensor	In the article, "The Impact of Biosensor Longevity on Diabetes Management" by Kim et al. (2020) in the journal Diabetes Technology & Therapeutics. This article discusses the importance of biosensor longevity for people with diabetes. The authors argue that longer-lasting biosensors can help people to better manage their diabetes by providing more accurate and continuous blood glucose readings. In the article, "*The Future of Diabetes Biosensors: Longer Longevity and Improved Accuracy*" by Patel et al. (2022) in the journal *Nature Reviews Endocrinology,* the authors argue that **longer-lasting biosensors could revolutionize diabetes management** by making it easier for people to track their blood glucose levels and make timely adjustments to their treatment.	**Dexcom G7**: The Dexcom G7 is a continuous glucose monitoring (CGM) system that was approved by the FDA in 2022. The G7 has a sensor that can last for up to 10 days, which is **twice as long** as the sensor on the previous generation of Dexcom CGM systems. **FreeStyle Libre 3**: The FreeStyle Libre 3 is a CGM system that was approved by the FDA in 2021. The Libre 3 has a sensor that can last for up to 14 days, which is **longer than the sensor on the previous generation** of FreeStyle Libre CGM systems.		
			It is possible to decrease the cost of a biosensor		A study published in the journal "*Nature Reviews Endocrinology*" in 2021 found that the **cost of diabetes biosensors has been decreasing over time.** The study found that the cost of continuous glucose monitoring (CGM) systems **decreased by an average of 20% per year** between 2012 and 2020 Another study published in the journal "*Diabetes Technology & Therapeutics*" in 2022 found that the **cost of CGM systems is still a barrier to access** for many people with diabetes		Some ideas for the possible ways to reduce the cost of a biosensor are; **Using more efficient manufacturing processes**: By using more efficient manufacturing processes, the cost of producing biosensors can be reduced. For example, 3D printing can be used to create biosensors more quickly and cheaply than traditional manufacturing methods. ***Developing lower-cost materials**: By developing lower-cost materials, the cost of the biosensor can be reduced. For example, researchers are developing biosensors that use less expensive metals and plastics.* **Using open-source designs**: By using open-source designs, the cost of the biosensor can be reduced. Open-source designs are made available to the public for free, which can help to reduce the cost of research and development. **Using economies of scale**: By producing a large number of biosensors, the cost of each biosensor can be reduced. This is because the fixed costs of manufacturing, such as the cost of setting up the manufacturing process, can be spread over a larger number of units. *out of these ideas, the most viable is to use alternative materials - such as plastics instead of etal for the body of the sensor, lowering the overall cost.*

<table>
<tr><td colspan="3">Feasibility Testing - EBD 2</td></tr>
<tr><td>Solution approach</td><td>Proof that it it doable (Proof of concept)</td><td>Comparisons and things to Consider:</td></tr>
<tr><td colspan="3"><u>FOR THE SENSOR</u></td></tr>
<tr><td>Optical Sensors:</td><td><u>Proof that products use the same technology:</u>
1) The Eversense sensor developed by Senseonics has successfully applied the implantable optical glucose sensors into a fully implanted CGM system, which can provide real-time measurements for glucose concentration for 180 days.

2) Nearly all of Apple Watch’s ability to monitor your cardiovascular health comes from the ppg sensor it uses - [https://www.helixapps.co.uk/blog/apple-watch-photoplethysmography-ppg]

<u>Proof that it's present in research papers:</u>
a) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10057625/
b) https://www.sciencedirect.com/science/article/abs/pii/S1746809421003037
c) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10057625

<u>Proof using open source:</u>
I) https://github.com/markolalovic/ppg-signal-extraction
II) https://www.mdpi.com/2076-3417/11/2/618</td><td rowspan="2">Both methods are non-invasive.

Optical sensors can give more accurate results and be more reliable than enzymatic sweat-based sensors as they constantly monitor blood sugar.

Sweat-based sensors can give false positives and false results as other molecules - like urea - may interfere, and hydration and sweat rates can differ, not only from person to person but within one individual itself.

Optical sensors have proven to be highly precise. However, they may also need calibration when considering the wrist circumference and blood vessel/skin thickness.

Both can be sensitive to the environment - but through the use of AI/ML, this risk can be minimised, especially for optical sensors, where only lighting may cause significant problems

Optical sensors, since continuously monitoring, have a better response time and ease of use. it also has a much longer life span - no denaturing/degradation of enzymes.</td></tr>
<tr><td>Sweat Sensors:</td><td><u>Proof that products use the same technology:</u>
I) USE OF ENZYME-BASED MONITORING:
i) continuously monitoring devices - Dexcom G7, FreeStyle Libre.
ii) use of enzyme-based technology in pinprick methods
II) USE OF SWEAT-BASED MONITORING HAS NOT BEEN DONE FOR THE MARKET

<u>Research papers confirming the fact:</u>
1) https://www.nature.com/articles/s41378-022-00443-6
2) https://www.nature.com/articles/s41598-022-06434
3) https://jast-journal.springeropen.com/articles/10.1186/s40543-022-00320

<u>Proof using open source:</u>
NOT FOUND</td></tr>
<tr><td colspan="3"><u>FOR THE APP</u></td></tr>
<tr><td>Image Recognition:</td><td>https://www.lftechnology.com/blog/ai/image-calorie-estimation-deep-learning/
https://github.com/Ravi-Teja-konda/trackMyNutrition/blob/master/EXPLORE_THE_CODE.md
https://vinayaksable2399.github.io/Food-Calories-Estimation-Using-Image-Processing/
https://www.irjet.net/archives/V11/i4/IRJET-V11I4304.pdf
https://azati.ai/portfolio/ai-calorie-calculator-and-food-recognition

Other examples of apps that use data - CalorieMama, WebMD, Calorie Control Council</td><td></td></tr>
</table>

Feasibility Testing - EBD 2		
Solution approach	Proof that it it doable (Proof of concept)	Comparisons and things to Consider:
Exercise Data:	**<u>Accelerometer and Positioning software:</u>** *https://www.vertexknowledge.com/post/how-do-smartwatches-measure-calories-tech-knowledge* - Smartwatches use their inbuilt accelerometer to measure your movements. They will also use their heart rate monitor to see how fast your heart is beating. Examples include the Xiaomi MI band, Samsung smartwatch, Whoop SmartWatch and other fitness trackers. ***Apple Watch***: The Activity app relies on arm motion and an accelerometer to track movement, but the Workout app can use the accelerometer, the heart rate sensor and GPS - *https://support.apple.com/en-in/105002#:~:text=The%20Activity%20app%20relies%20on,heart%20rate%20sensor%20and%20GPS* **<u>Heart Rate monitoring:</u>** **Reliance Smartwatches**: measure heart rate by scanning blood flow near your wrist, by illuminating it with LEDs. The colour green is chosen, because it is absorbed well by our red blood, so optical sensors can gauge the flow of blood and heartbeats more accurately - https://www.reliancedigital.in/solutionbox/watch-your-heart-beat-is-your-fitness-band-lying-to-you/ Nearly all of **Apple Watch's** ability to monitor your cardiovascular health comes from the ppg sensor it uses - [https://www.helixapps.co.uk/blog/apple-watch-photoplethysmography-ppg]	I) use of the app that has the features or connects to the smartwatch to use the smartwatch features II) partnering with companies to add these additional features to the app III) subscription fee for long-term use and full access to features - e.g., Rs. 300?
Use of AI/ML to aid the App:	Big manufacturers (Apple, Fitbit, Samsung etc.) use AI (artificial intelligence) to compare lots of data to reduce the percentage of error. And on top of that, the ML (machine learning) methods help to improve the logic for the individuals by comparing the data from day to day - *https://www.vertexknowledge.com/post/how-do-smartwatches-measure-calories-tech-knowledge* https://www.january.ai/ - uses predictive AI to show you the impact of food before you eat it. Avoid blood sugar spikes and manage blood sugar levels, Healthy eating made easy with clinically backed behaviour change, Lose weight by optimizing nutrition and logging food https://www.nature.com/articles/s41598-022-06434 https://azati.ai/portfolio/ai-calorie-calculator-and-food-recognition	**1) individuals' lack of technical expertise** - not necessary to consider as the app will have an easy user interface and mostly clinical data will be taken from the device itself and sensor - backend processing will happen via the cloud, and the user will have little to no interference with the actual algorithms except for basic food data inputs **2) Data governance issues** - data privacy, safety and security in the app are essential to keep in mind - use of access levels and encryption to maintain confidentiality of data. Use of privacy consent forms to share data to the app, transparent policies, and regulate the data the system obtains to prevent unethical decisions. **3) low data quality** similar data will be used throughout due to the sensor being standardised and calibrated for each individual - data that doesn't reach necessary quality requirements can be scrapped. using statistical techniques such as r2 and standard deviation, we can also set limits within the system itself to ensure that low-quality data doesn't affect AI. **4) high cost of AI** - The supply-to-cost ratio can lower the total price of the AI system as more and more individuals use and buy the product - it can also have small added subscription fees for access to high-end processing. Examples of case studies for this: https://www.jiobook.com/

Glucose Biosensors: Where we will go in the future

By: Ishani Sanyal

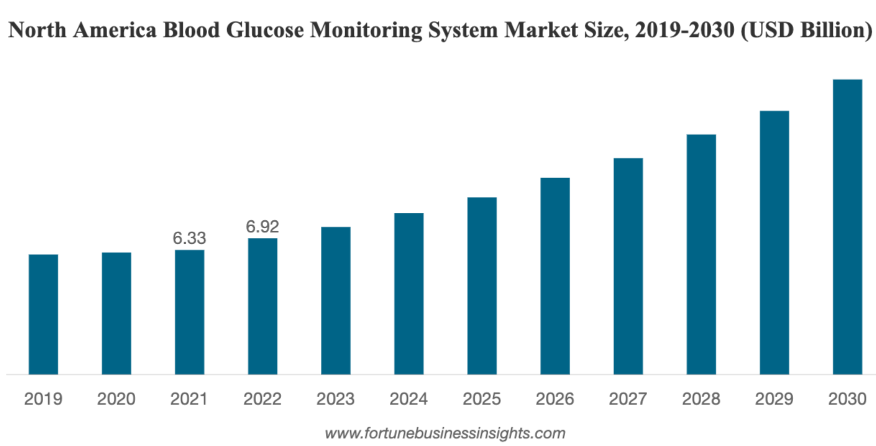
Diabetes is one of the most widespread diseases in the world today. It affects more than 422 million people, ranging majorly from low to medium-income backgrounds (World Health Organization). Caused by insufficient insulin production or increased insulin resistance, diabetes is known to be linked to severe medical consequences such as heart disease, loss of vision and ailments in the kidneys (Centers for Disease Control and Prevention).

Yet, despite its prevalence in our society, we have yet to find a cure for this non-communicable disease, and it is imperative to be able to monitor and manage diabetic patient conditions.

Widely accepted in the medical world, measuring blood sugar has been an efficient mechanism in the management of diabetes (Yoo and Lee). Blood sugar is a key indicator of the glucose [and thereby: insulin] levels in your body. It enables medical professionals to diagnose patients and help regulate their conditions by determining the need for additional medication, insulin pumps or other external tools.

A glucose biosensor is a device that facilitates the supervision of blood sugar levels. Over the past few decades, there have been significant advances in the technology used in biosensors, as they progressed from lab-based detection to self-monitoring blood glucose(SMBG) biosensors to continuous glucose monitoring(CGM) sensors.

Overall, the glucose biosensor market has been valued at 15.8 billion USD and is projected to proliferate as more and more technology is developed (Fortune Business Insights)



A glucose biosensor is generally made of three main sections; a recognition element that quantifies the target molecule specifically [without being interfered with by other chemicals], a component that transforms the target molecule capacity into a measurable signal [a transducer], and finally a processing device that converts the signal into a readable form for us. (Yoo and Lee)

While most biosensors make use of enzyme-based technology for the recognition of glucose, we can use various other means, such as receptors, antibodies and microorganisms. Even transducers can be categorized into electrochemical, optical or thermometric transducers.

(Johnston et al.)

The majority of glucose sensing methods rely on glucose being, not only detectable in the substance that is being chosen to measure but also rely on the changing of blood glucose levels (concerning the levels of blood sugar) to be detectable. Body fluids that can be used to measure this change are blood, sweat, interstitial fluid, saliva, urine, tears and serum.

The most popular form of measuring blood sugar, currently, is the finger-prick method. A patient wanting to measure their blood sugar levels would use a sharp pin to break through the skin on the tip of their finger to obtain a drop of blood. The glucose in the blood would then be measured, enabling the monitoring of the body's condition.

This method, though reasonably accurate, is painful when repeatedly used and does not help predict or warn patients of incoming hyperglycemic attacks. Furthermore, these tests have been known to lead to possible infections when used regularly, and can even lead to the loss of feeling in the fingertip areas.

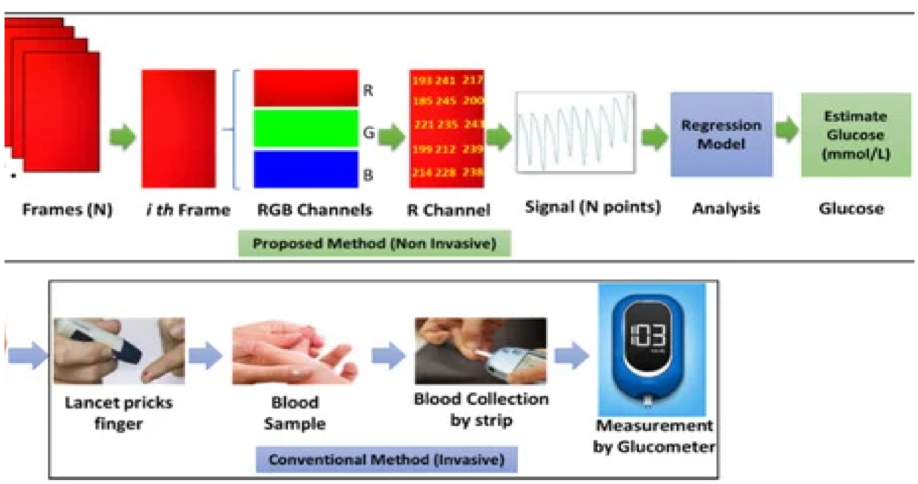
Therefore, the future of glucose biosensors lies in non-invasive mechanisms of measuring blood sugar levels in patients. Demand for safe, continuous monitoring and less painful approaches to measuring blood sugar has been at an all-time high, with various minimally invasive and continuously monitoring sensors entering the market, including Dexcom Inc.'s G6/G7 models and Abbott's Freestyle Libre sensor.

These sensors rely on measuring the sugar levels in a patient's interstitial fluid [the extracellular fluid outside of blood vessels] via enzyme-based techniques and allow a user to monitor their blood sugar levels at a sustained rate. However, the lifespan of the devices is limited - lasting approximately 10 - 14 days - and the cost of the device is far above the range of the average to low-income families who are most afflicted by the condition.

Keeping these problems in mind, with the development of newer technologies in biology and medicine, wearable devices have made significant advances and can be considered a possible proponent of non-invasive sensors. They provide a platform that enables the tracking of and the continuous monitoring of blood sugar and can possibly be modified to allow for the measurement of external body fluids such as sweat.

Additionally, newer methods of measuring blood sugar can be commercially introduced. Possibly, the use of PPG (Photoplethysmography) based light signalling mechanisms can be used. PPG light signalling is already conventionally wielded in oximeters or heart rate monitors [such as in smart watches], and its techniques can be further implemented in the glucose biosensor field.

PPG works based on the reflection of light. Once a PPG-based infrared beam passes through a medium, depending on the number of particles the medium has, a certain amount of light is reflected. Therefore, it is evident that the relation between reflected light and blood sugar is indirectly proportional [the more sugar molecules present in blood, the less light is reflected]. There are a variety of researchers who are experimenting with these relationships and techniques, using the addition of machine learning to supplement their results.



(Islam et al.)

Work around innovation in the biosensor industry continues and more and more methods are being developed for the market and the demand of the customers. There is a significant focus in the noninvasive and continuous monitoring biosensor area and more and more investments are going into it. In the near future, a product that is cheaper, more accurate, and meets all the requirements will be, hopefully, developed.

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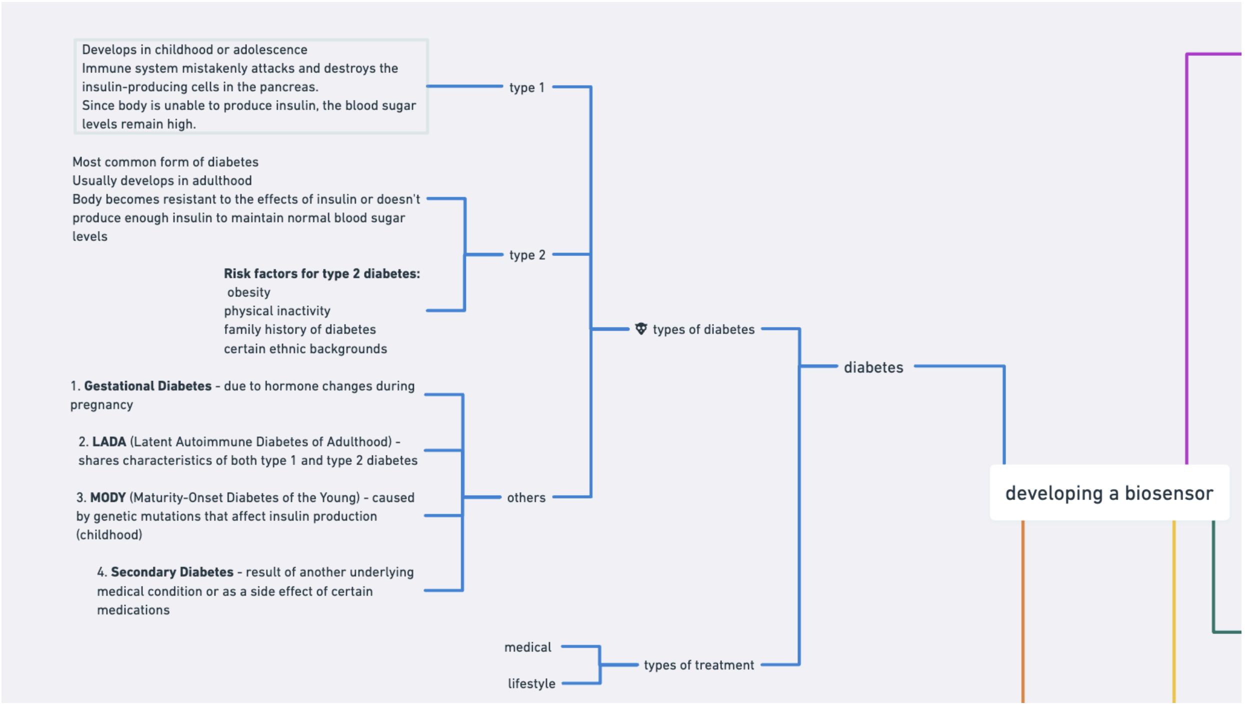
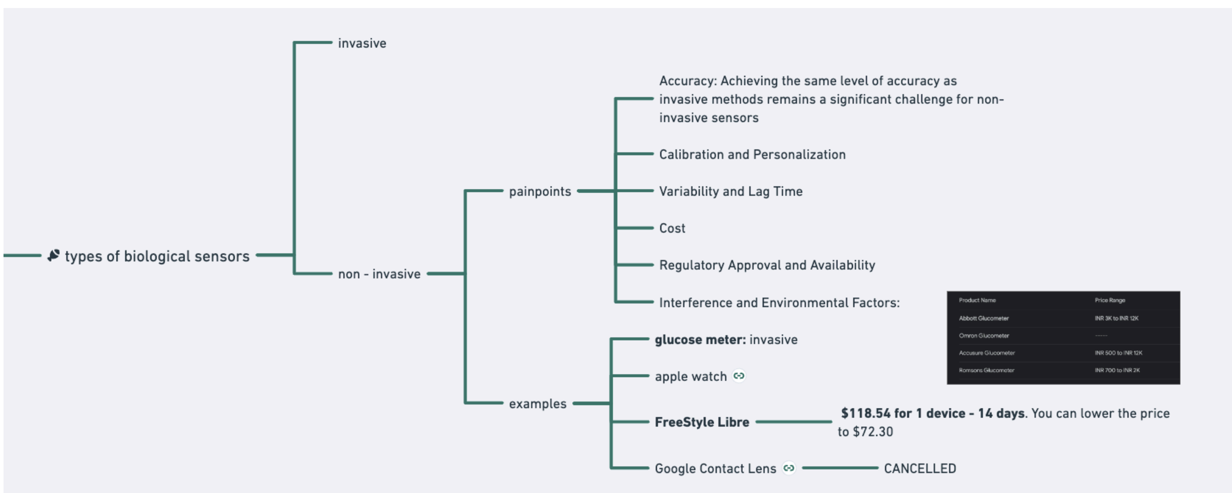
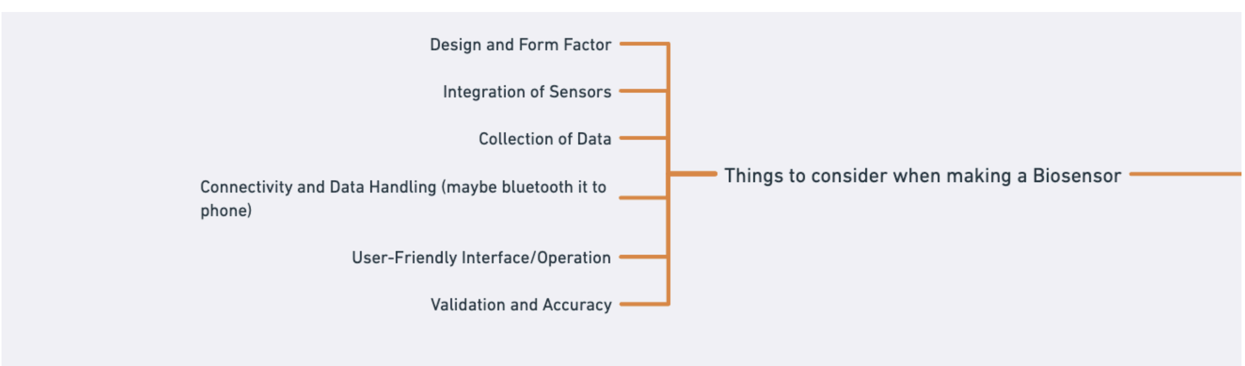
Background Research:



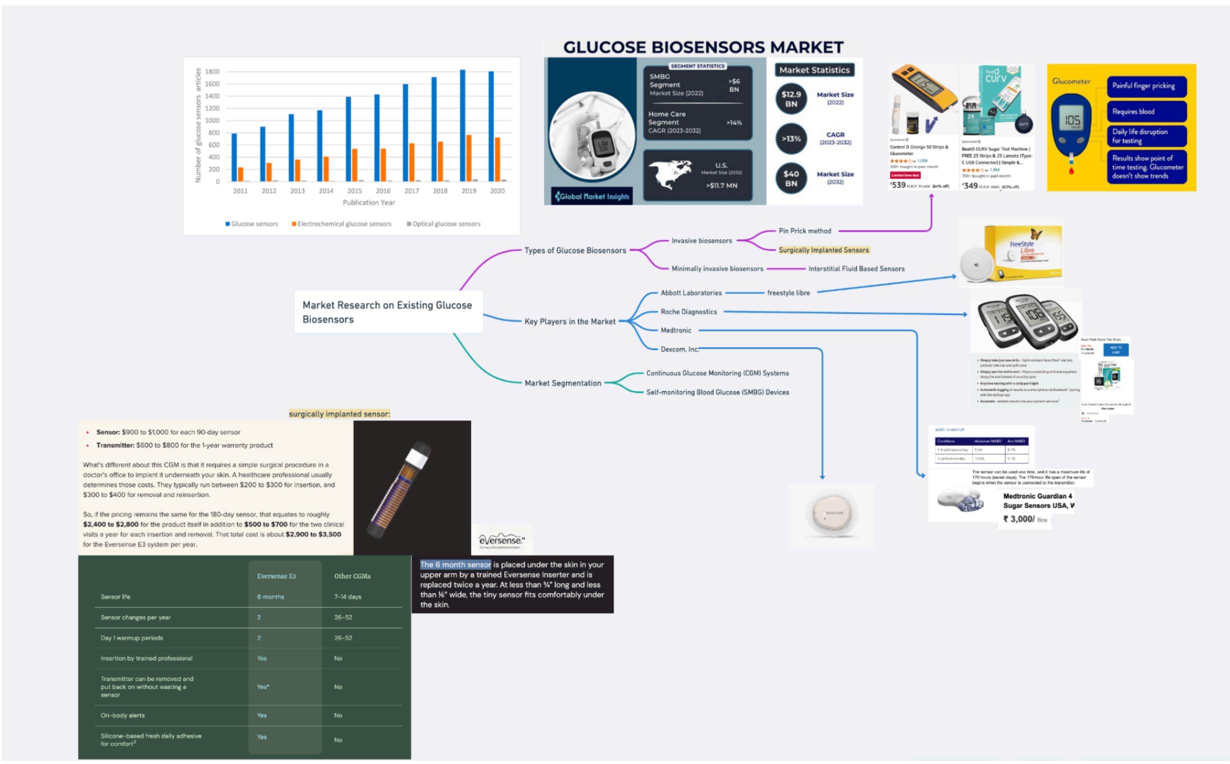




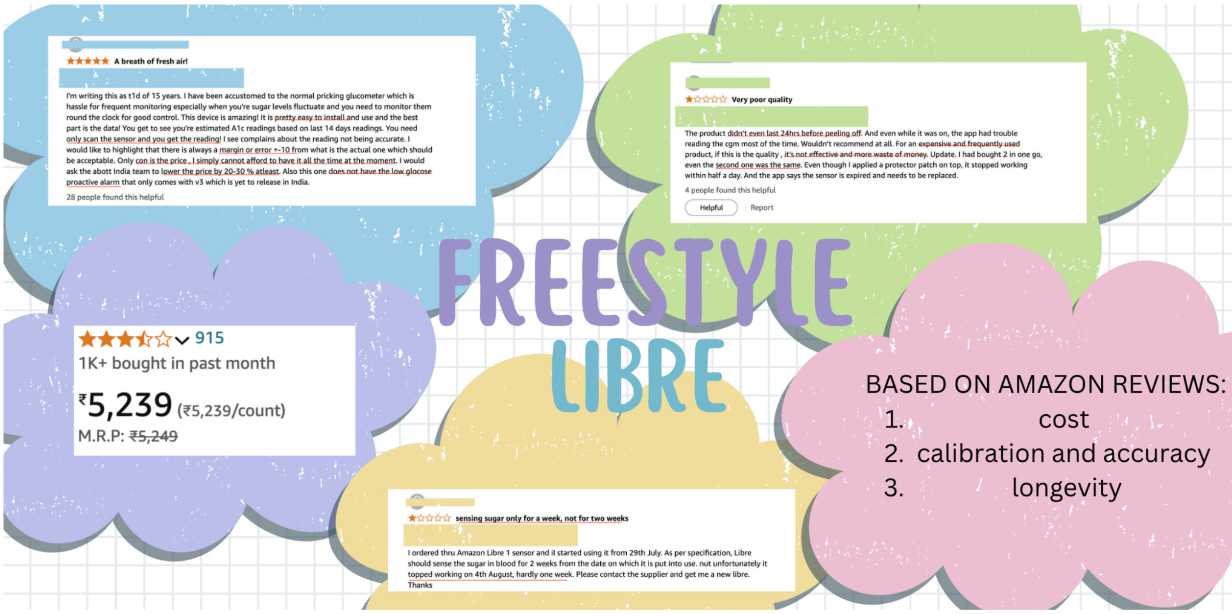
Market Research

pain points of existing sensors

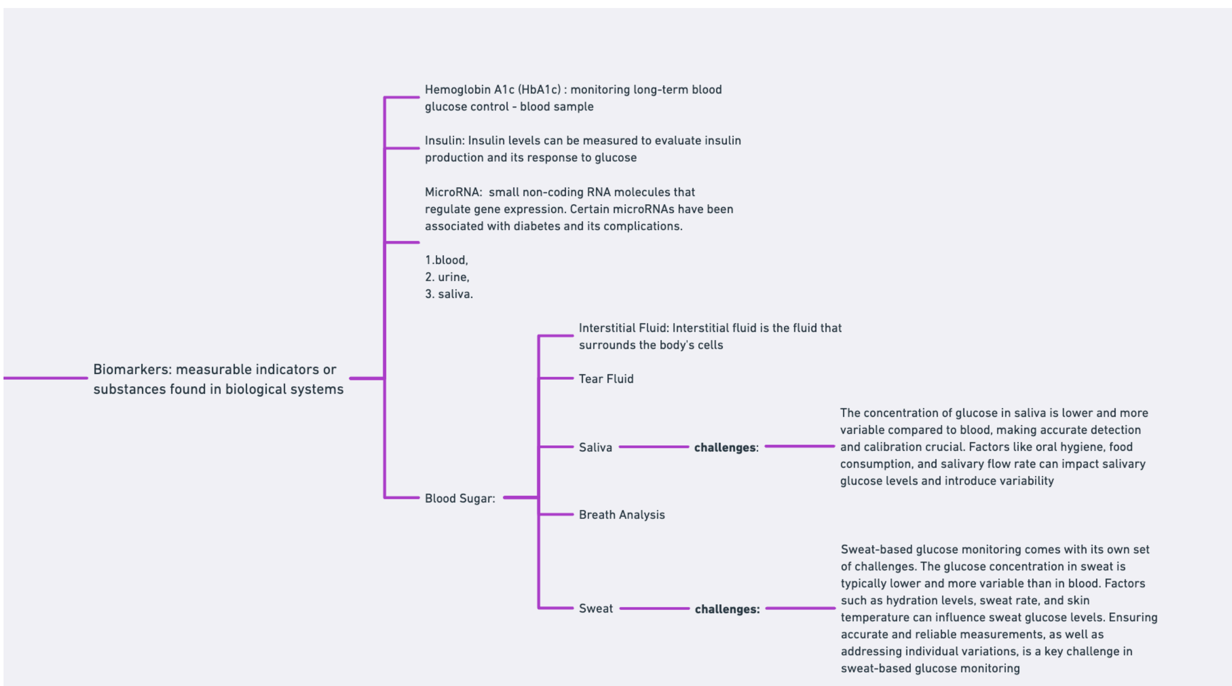
- Invasive Nature: require invasive procedures, such as finger pricks or subcutaneous implantation of sensors, to obtain blood samples or monitor glucose levels
- Calibration and Accuracy: Some biosensors require frequent calibration to maintain accuracy, and variations in calibration techniques or errors in calibration can affect the reliability of glucose measurements
- Delayed Glucose Readings: Biosensors often have a delay between the actual glucose level changes in the bloodstream and when they are detected by the sensor
- Sensor Longevity and Stability: Biosensors may have limited lifespans, requiring frequent replacement or recalibration
- Cost: Some biosensors can be expensive, making them less accessible to individuals with limited financial resources.



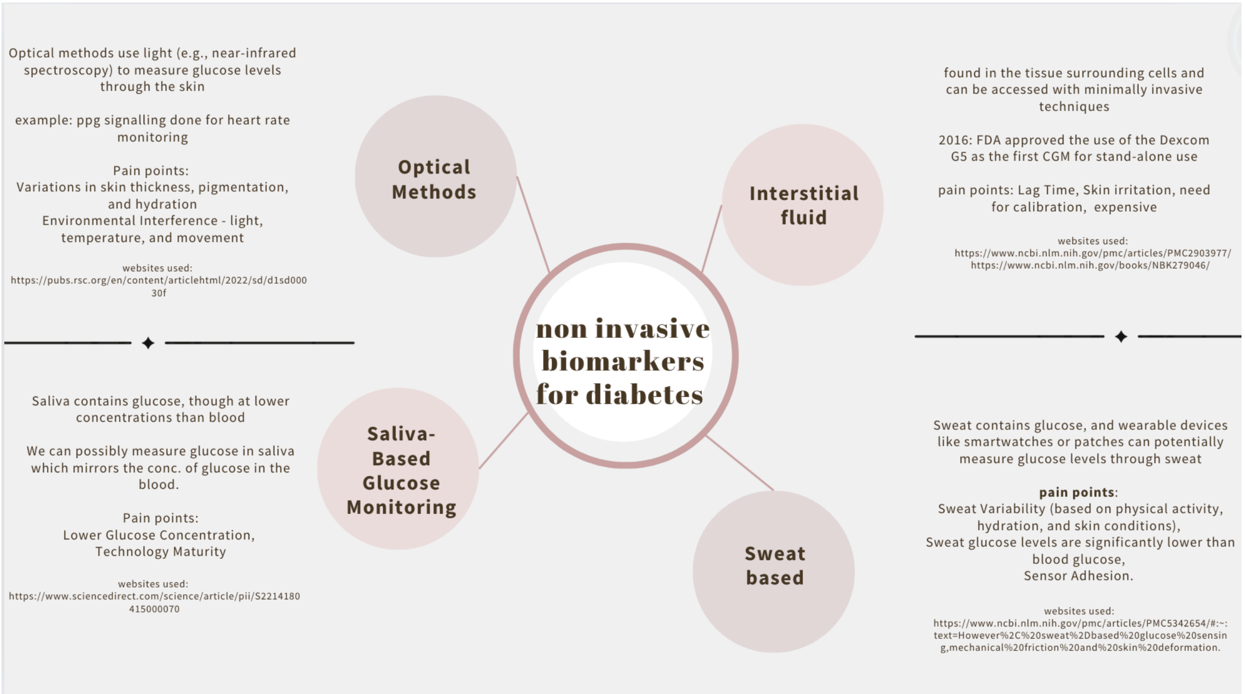
	Eversense E3	Other CGMs
Sensor life	6 months	7-14 days
Sensor changes per year	2	26-52
Day 1 warmup periods	2	26-52
Insertion by trained professional	Yes	No
Transmitter can be removed and put back on without wasting a sensor	Yes*	No
On-body alerts	Yes	No
Silicone-based fresh daily adhesive for comfort[3]	Yes	No



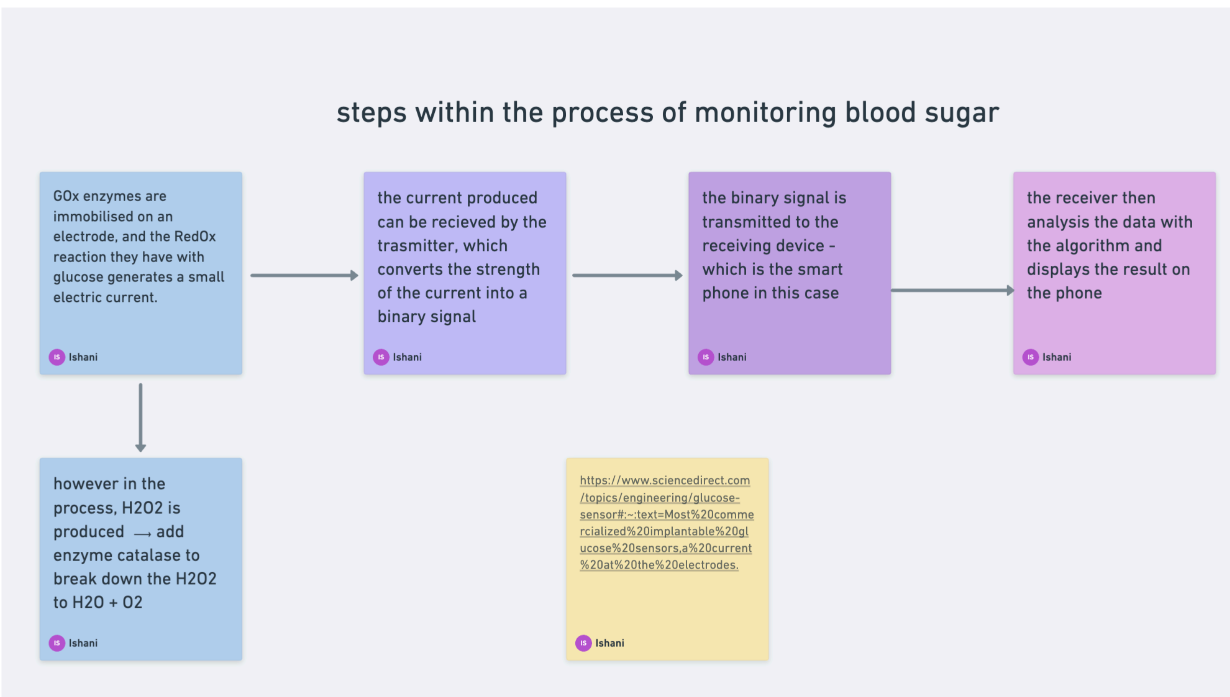
Biomarkers and Research on the types of sensors;



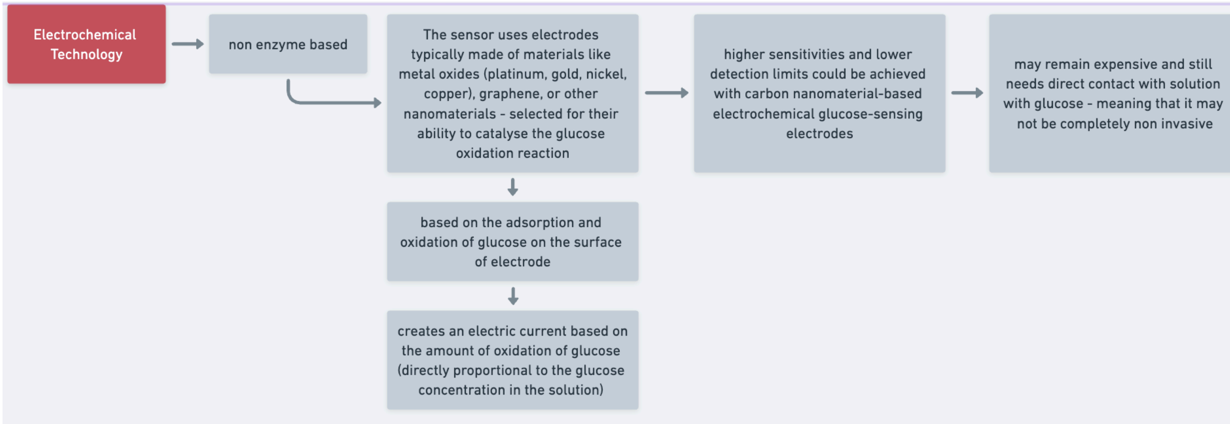
Types of biomarkers we can use:



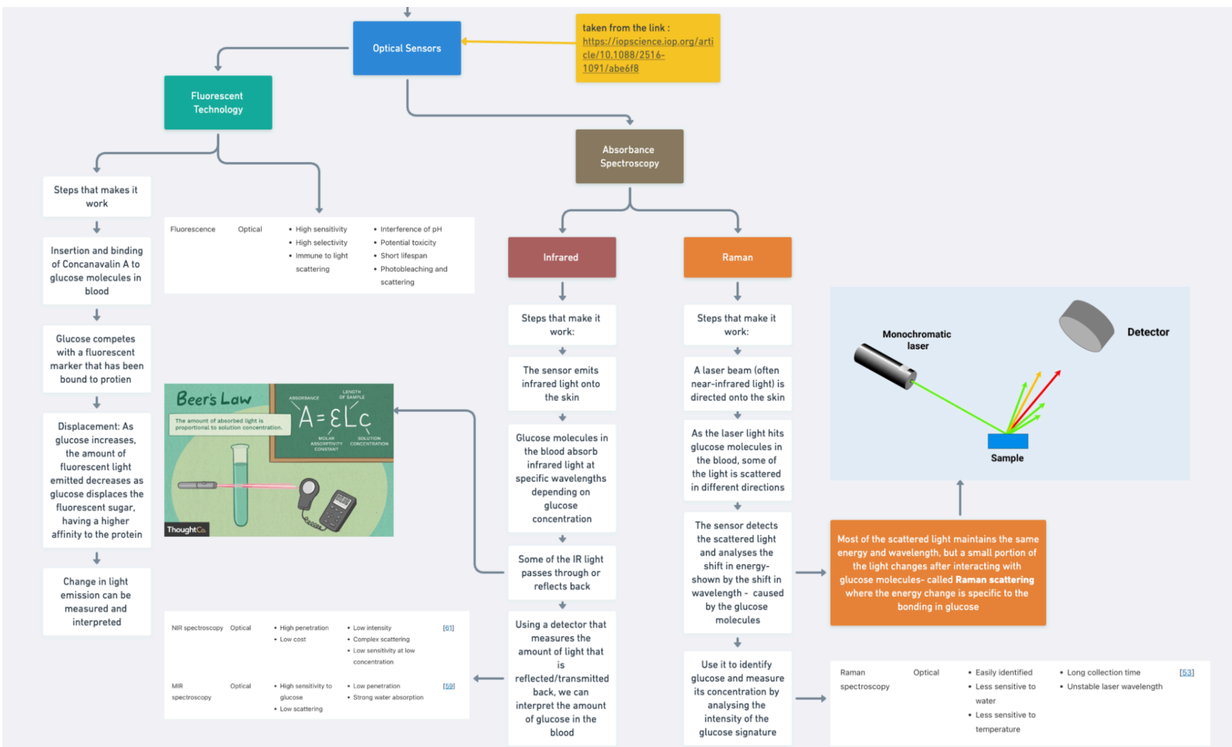
How an interstitial fluid enzyme-based sensor works (sweat-based works on the same concept):



Electrochemical sensors :



How an optical sensor works:

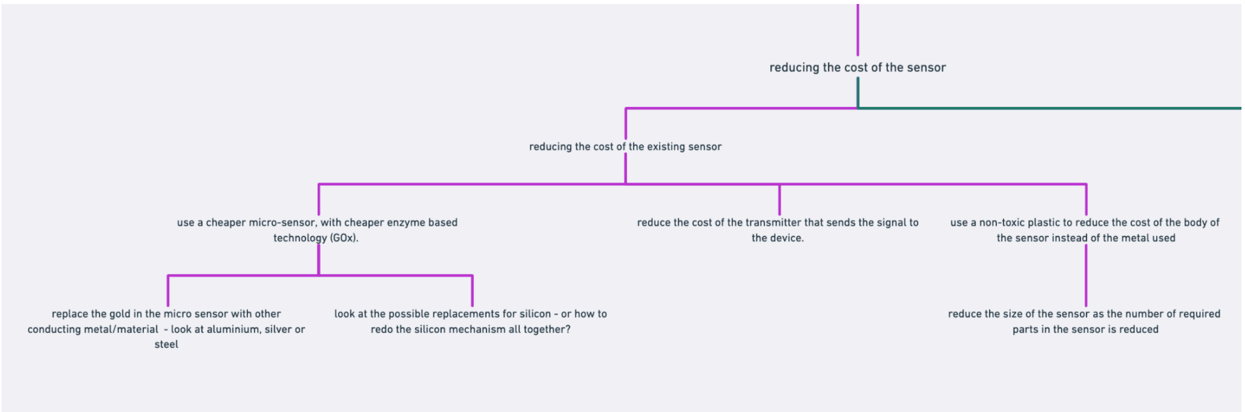


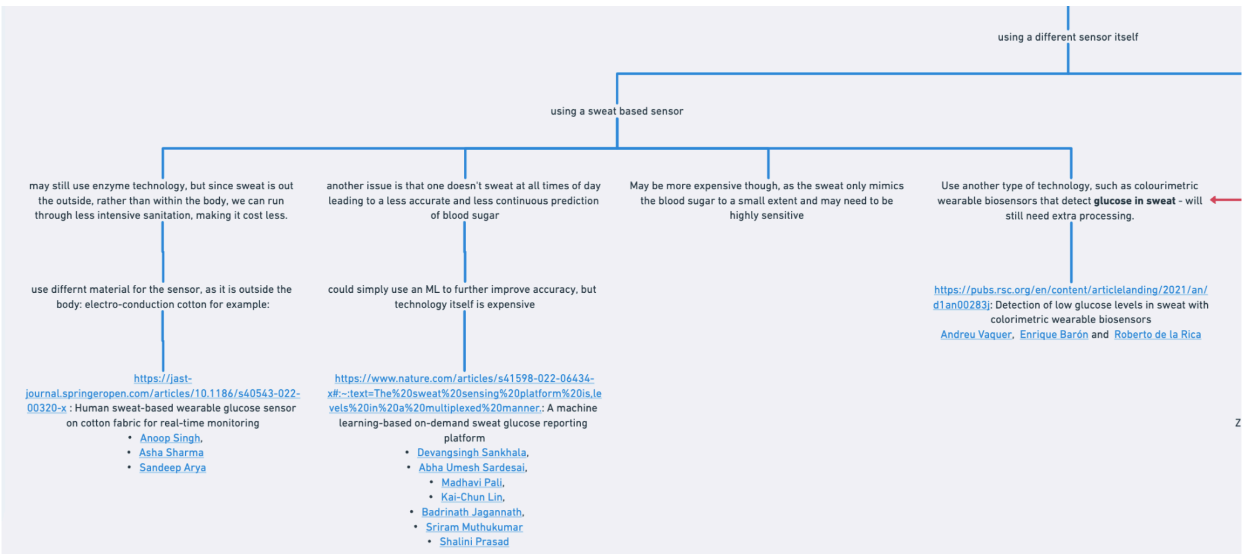
Building an idea

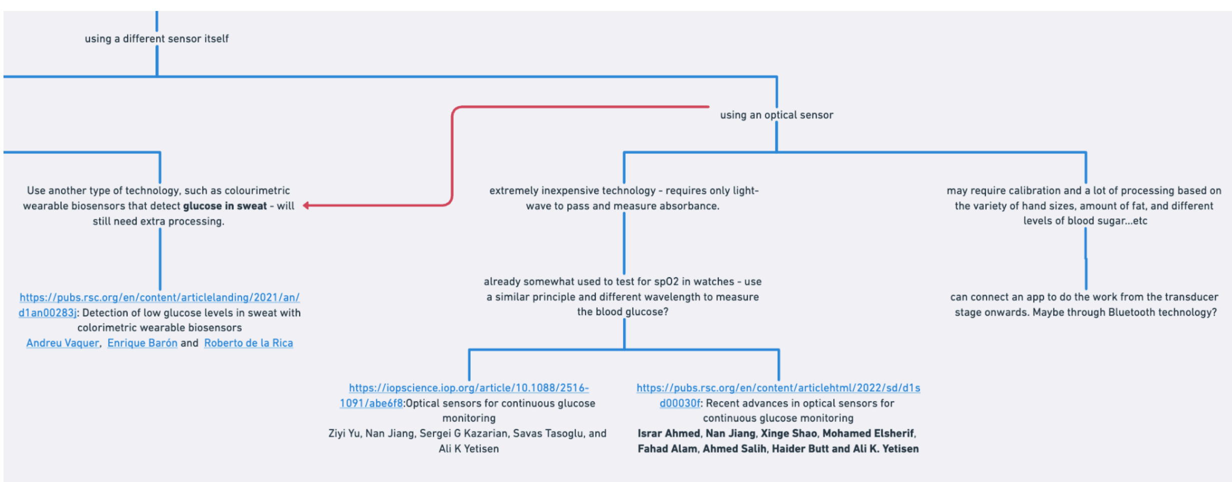
possible ideas/ unique angles include

1. use of AI and machine intelligence in analysis of data
2. making it more accurate and reliable
3. cost??
4. instead of data analysis in device, use phone
   https://web.iitd.ac.in/~sandeepjha/files/2017%20Soni%20and%20Jha%20Anal%20Chim%20Acta%20996%2054-63.pdf
5. make it more long lasting

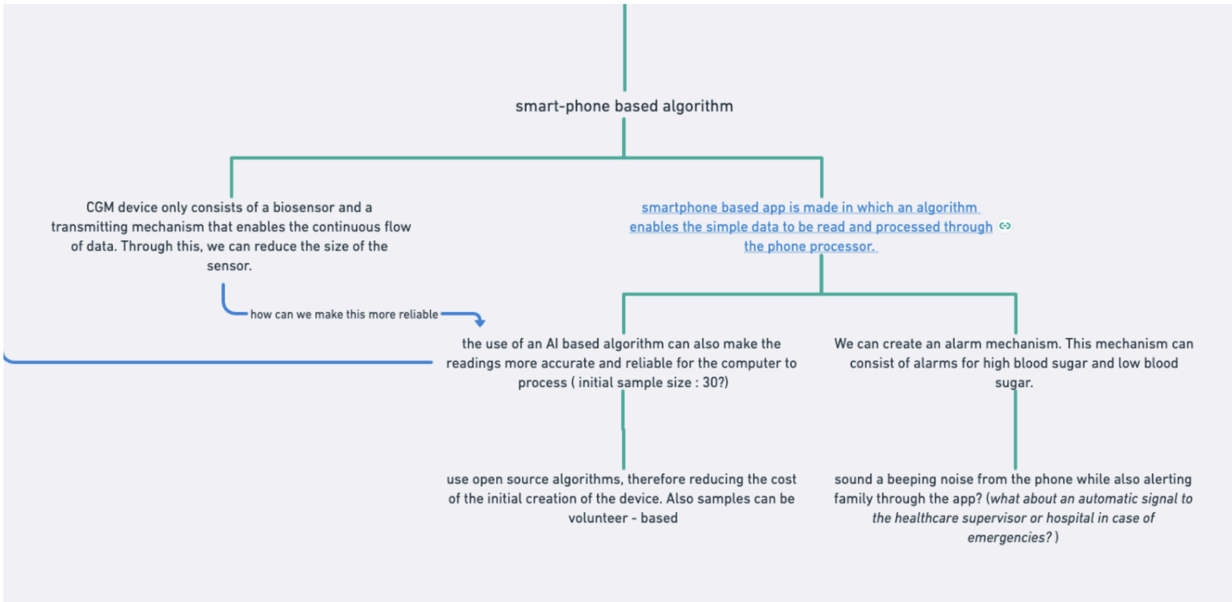
How to reduce the cost of the sensor:

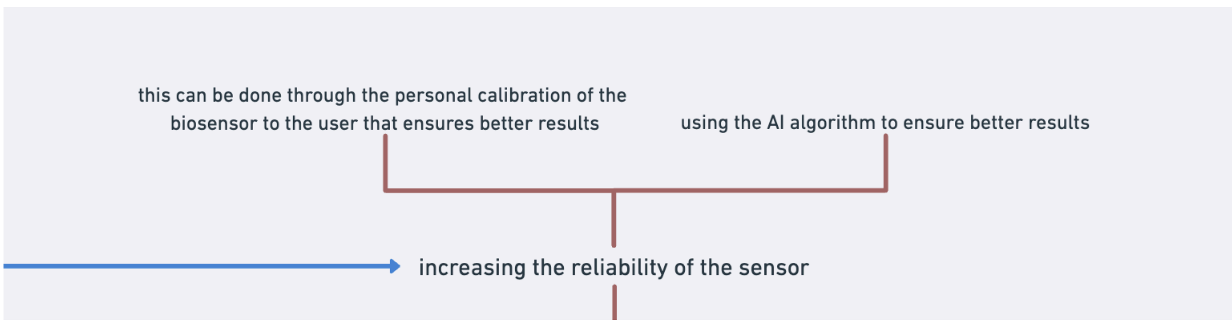






How to maintain/ improve accuracy





How to reduce manufacturing costs: