NNs, CNNs, GNNs and ASD

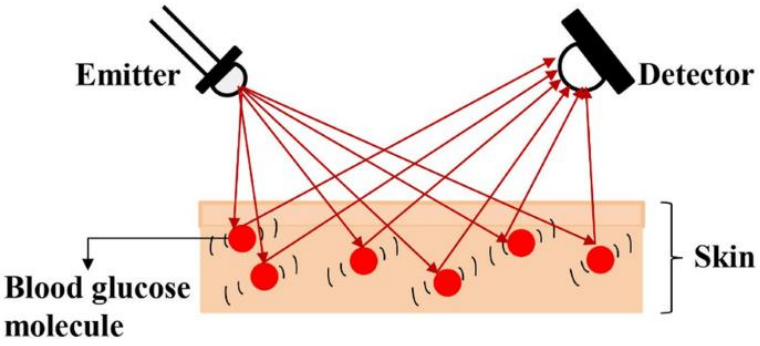
Concepts, mechanisms

i. How is non-invasive glucose monitoring actually done?

Ref: https://pmc.ncbi.nlm.nih.gov/articles/PMC10331674/

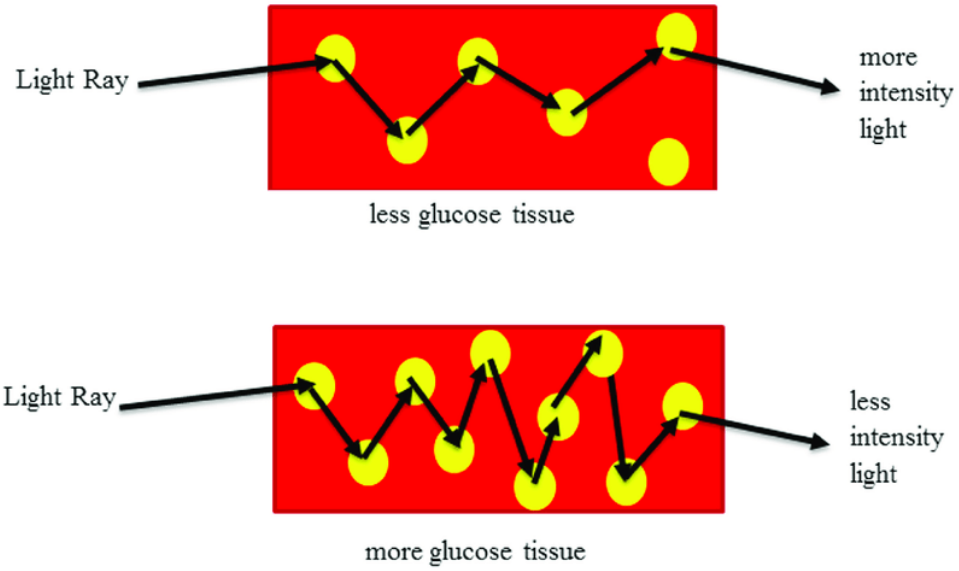
Non-invasive glucose monitoring employs an optical technology called **N**ear **I**nfra**R**ed Spectroscopy or **NIR** spectroscopy.

To measure glucose levels using near-infrared light, the light must be absorbed by the glucose molecules and scattered by other chemicals in the tissue. Near-infrared spectroscopy generally selects areas with rich blood vessels and thin skin, such as the fingertips or earlobes, for measurement.



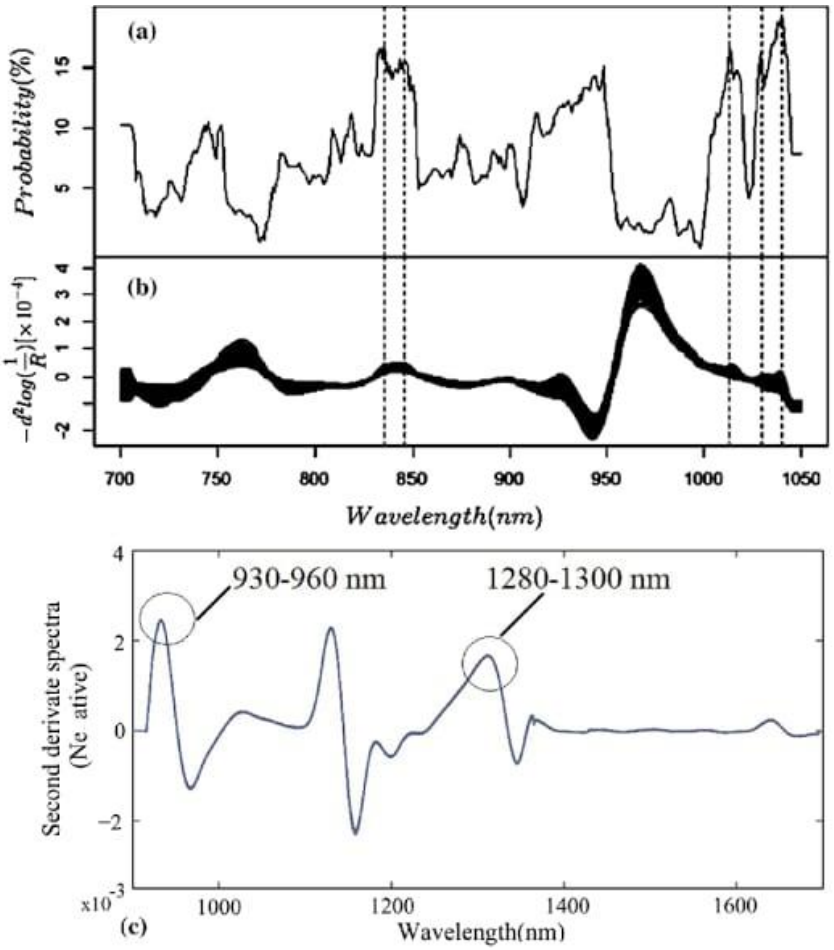
ii. How does glucose react when NIR light is shined on it?

As seen above, glucose absorbs and scatters the NIR light that falls on it. This can be used to our advantage in the sensor. When we shine NIR light through the skin, we can estimate the amount of glucose by the intensity of NIR light that is reflected back. More glucose = less intensity of NIR light is reflected back; because the glucose molecules have absorbed most of it. And vice versa. The absorption is due to glucose molecules vibrating (NIR's light energy is transferred to kinetic energy).



iii. At what wavelength of NIR light is absorption by glucose maximum?

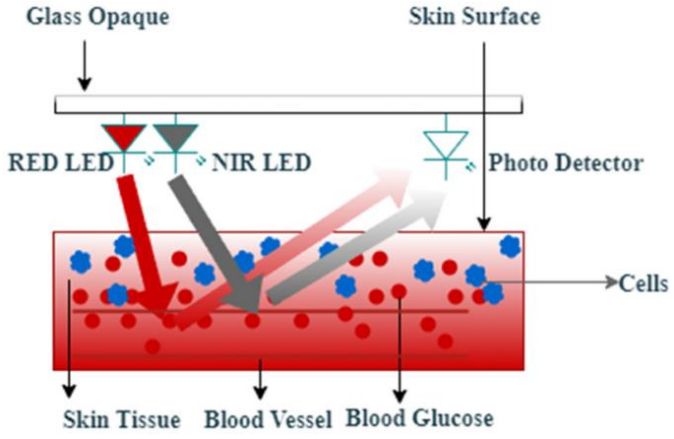
Near infrared is a broad spectrum. It goes from 800 nm to 2500 nm. You may wonder at which exact wavelength is glucose absorption maximum. Research has been done in this field.



While glucose absorption peaks around 950nm, while there are secondary harmonic oscillations (vibrations) at <850nm range too.

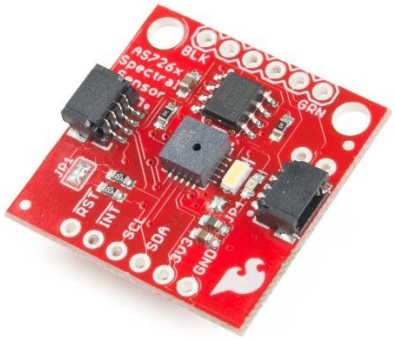
iv. How would the sensor for this purpose work?

The concept of sensor is pretty simple: We need an NIR emitter to shine light through the skin, and we need a detector (photodiode) to capture the intensity of the light that is reflected back after getting absorbed by the glucose molecules)



v. Why are we using the AS7263 NIR spectroscopy sensor?

Must know: Spectroscopy is the study of how matter interacts with light.



The AS7263 NIR sensor would be the perfect fit for capturing blood glucose levels non-invasively using Near Infrared Light. It offers six channels of different wavelengths.

610 nm **Violet**
680 nm - **Blue**
730 nm - **Green**
760 nm - **Yellow**
810 nm - **Orange**
860 nm – **Red**

All these channels have a ±20 nm bandwidth.

NOTE: These six channels indicate that the AS7263 sensor can shine light of these specific wavelengths and capture the intensity of the light that is received back.

The output of the sensor will look like this:

```
Violet   68.96146392
Blue     51.3706932
Green    52.60161972
Yellow   99.20008087
Orange   821.241333
Red      2802.54882812
Temperature 24c: 32f
```

We will mostly be interested in the 'Red' channel because it has the 860 ±20 nm wavelength capability and can capture the glucose molecule's secondary harmonic oscillations (vibrations) at 850 nm range as seen above in concept **(iii).**

The sensor can be operated with the `GetCalibrated()` function which will quickly flash the emitter of the sensor for a fraction of the sensor to get the values and print them to our output.

vi. How would our NN look like?

A neural network model consists of 3 components: Input layer, hidden layers and output layers.

The input layers would consist of input nodes that determine what we want as an output. In our NN architecture, the input layer would be the AS7263 sensor's analog output values and then the output layer would be the glucose level that is present in our blood

This sensor would be placed on the skin. As we are making a watch-type of sensor module, it would be placed under the watch, pressed against the wrist. Let us see what parameters would actually affect the output of this sensor.

➔ For capturing the glucose value in the blood, we can operate the **'Red'** channel.

➔ Skin tone might also affect capture; so, we can also consider the **'Yellow'** and **'Orange'** channels because all skin tones are essentially lighter or darker shades of orange or yellow. Lighter skin tones will have a higher **'Red'** channel output as light shines through easier. Therefore, skin tone must be taken into account and negated during the NN calculation, so as not to affect the actual blood glucose output.

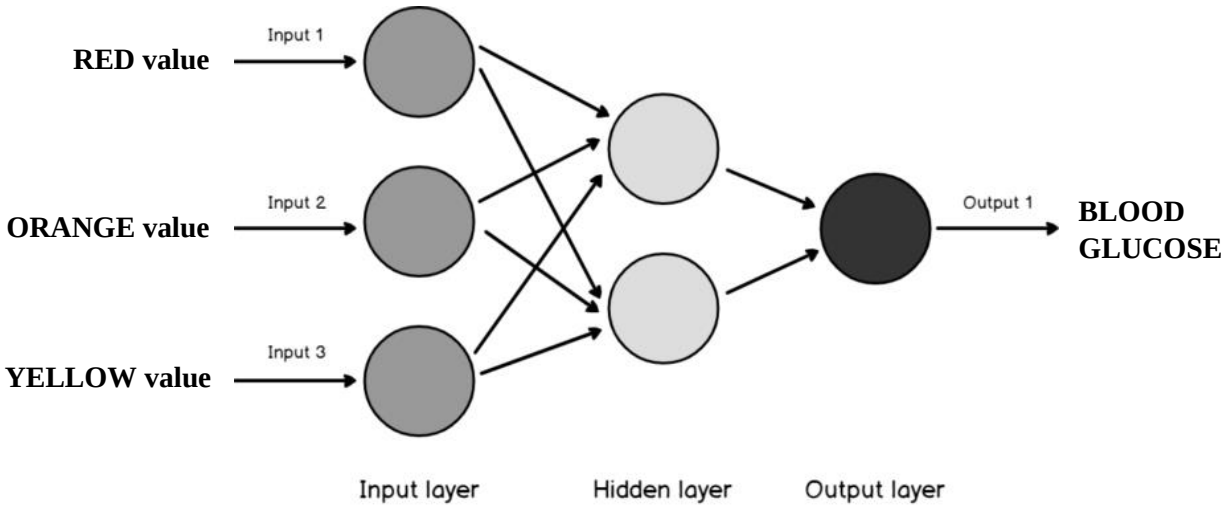


IMAGE NOTE: Hidden layers are just a sample representation here. The number of hidden layers and the number of neurons in each hidden layer can only be determined by hyperparameter tuning while making the actual NN.

vii. Dataset for our NN?

For the initial review, we will be using an artificially generated dataset to just give a glimpse of our NN architecture. After we get the sensor, we might have to start creating our own dataset by collecting the values of the RED, ORANGE, YELLOW values from the AS7263 sensor and mapping it to our actual blood glucose level.

This dataset will be later split into training and testing datasets, and be used to train the actual Neural Network model.

Comparison with other techniques/sensors:

Sensor	Advantages	Disadvantages	Detection site
Near-infrared spectroscopy	No risk of infection, strong penetration, low cost.	Affected by environmental changes (such as temperature, humidity, pressure).	Subcutaneous tissue
Gold nanostructured flexible sensor	Good flexibility, excellent selectivity, repeatability, and stability.	The activity of various enzymes must be ensured, and the requirements for storage and use are high.	Sweat
Flexible N-GQD/PANI nanocomposite layer sensor	Has high sensitivity and repeatability, and stability, and can effectively overcome the fluctuations of biological signals.	The requirements for the materials are high, and the manufacturing cost is high.	Sweat
Electrochemical dual-channel sensor	Suitable for continuous monitoring during sleep, high blood glucose correlation.	Low flexibility.	Subcutaneous blood
Polarimeter	No risk of infection, and low cost.	Long detection time, may cause harm to the human eye.	Aqueous humor, the cornea
Electromagnetic sensor	Personalized detection, high accuracy.	High detection cost.	Subcutaneous blood
Microwave sensor	Good real-time performance, small size.	Easily interfered with, low accuracy.	Fingers

Disadvantages of other blood glucose samples: (ISF: Interstitial fluid)

Sample	Disadvantages	Electrode Materials	Sensitivity
Saliva	• Many interfering impurities; • Low correlation; • Breeding bacteria; • Low sensitivity; • Hysteretic	SWNT-CS-GNp	26.6 $\mu A\ mM^{-1}$
Tears	• Low comfort; • Energy supply problem; • Poor precision; • Hysteretic	PTB-GOx	0.421 $\mu A\ mM^{-1}$
Sweat	• Every analysis needs to sweat, not suitable for diabetics; • Hysteretic, breeding bacteria	Nano-Gold	23.72 $\mu A\ mM^{-1}$
ISF	• Low comfort; • Skin irritation • Hysteretic	Nano-Gold	130.4 $\mu A\ mM^{-1}$ – 158.0 $\mu A\ mM^{-1}$