An
Introduction
to

PULSE OXIMETRY

PRESENTER:

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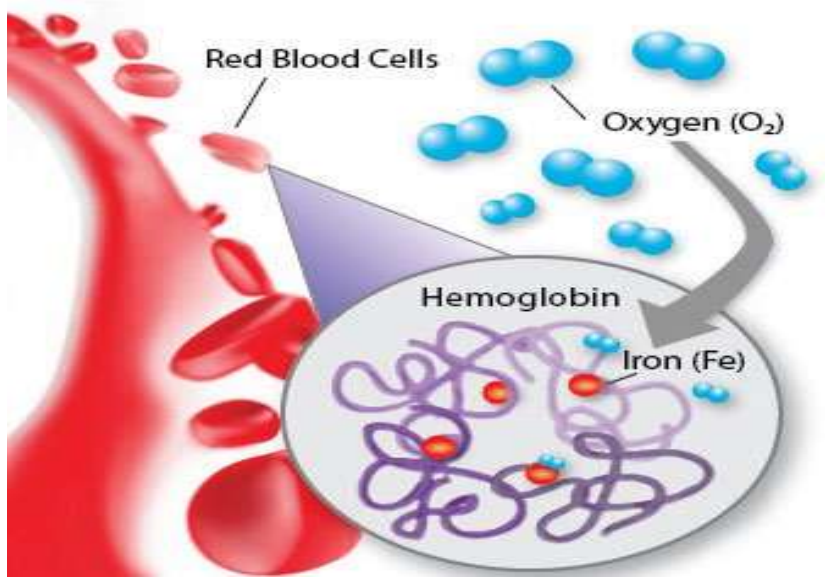
Introduction

- The maintenance of optimal 02 delivery is the core concern during anaesthesia
- “Oxygen lacks not only stops the machinery, but wrecks the machinery” – J.S Haldane
- Monitoring of oxygenation using pulse oximeter avoids many catastrophes

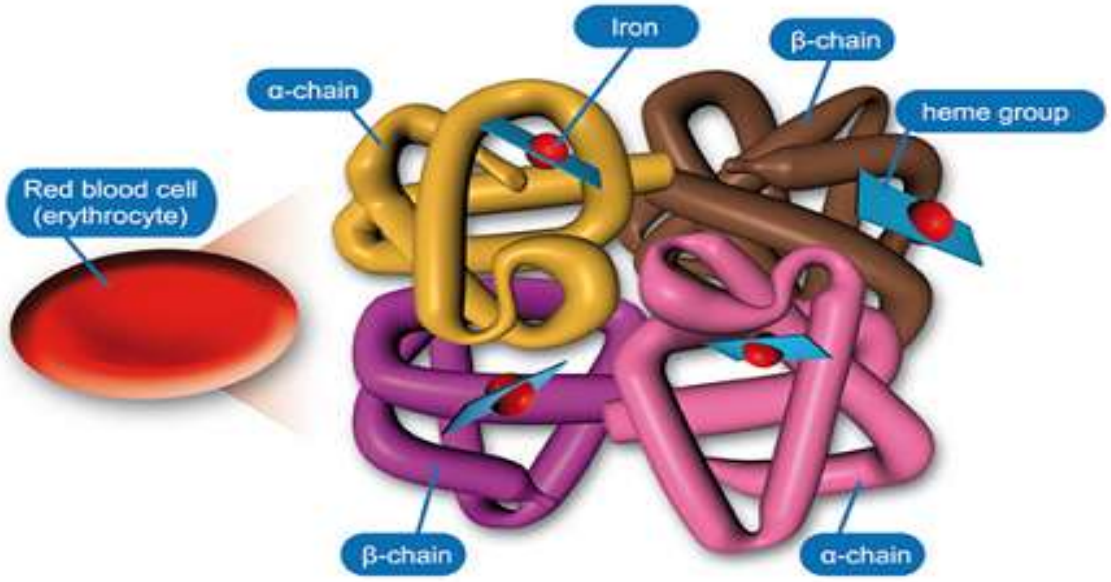
Hemoglobin

- **Hemoglobin (abbreviated Hb) is the iron containing oxygen transport mettaloprotein in the red blood cells of the vertebrates.**

- **Hemoglobin transports oxygen from the lungs to the rest of the body, where it releases the oxygen for the cell use.**



Hemoglobin/ Haemoglobin



A Protein That Carries Oxygen From Lungs to Tissues Throughout the Body..

Definition

PULSE OXIMETER is used to measure oxygen saturation in the body i.e how much of the hemoglobin in the blood is carrying oxygen.

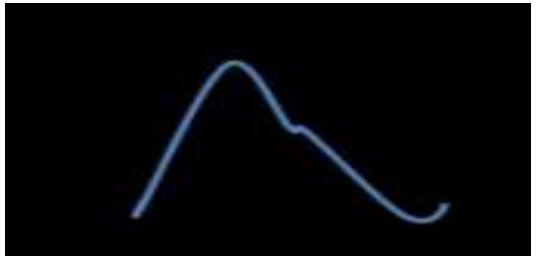
- Pulse oximetry, sometimes called the fifth vital sign, is a non-invasive method of measuring hemoglobin saturation (SpO2) by using a light signal transmitted through the tissue

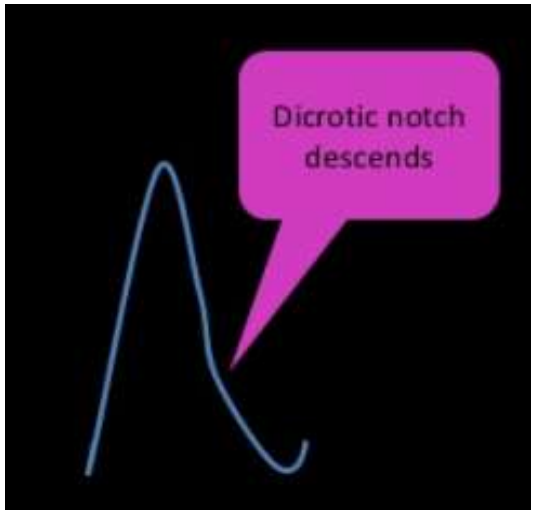
- A low SpO2 can provide warning of hypoxemia before other signs such as cyanosis or a change in heart rate are observed.

- It is one of the most essential monitors for routine use in anesthesia and intensive care

Pulse Oximetry

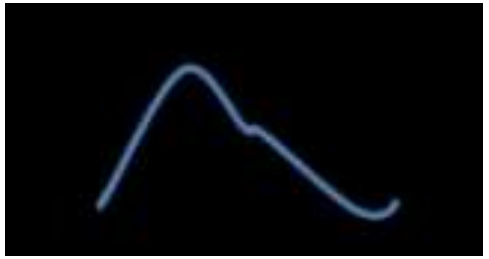
- **It measures the heart rate**
- **Gives an idea about tissue perfusion by pulse wave form**





Increased amplitude indicates vasodilation

Decreased amplitude indicates vasoconstriction



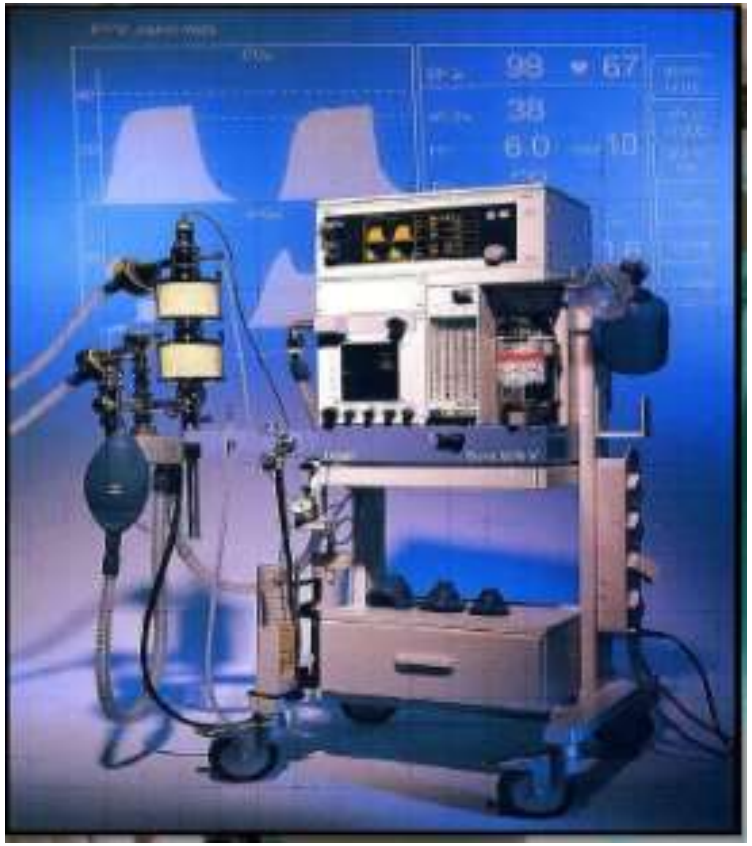
- Percentage of Hemoglobin (Hb) that is saturated with oxygen

The oxygen saturation (SpO2) is a measure of how much oxygen the blood is carrying as a percentage of the maximum it could carry and is sometimes referred to colloquially as the "sats" reading.

Heart rate refers to the number of times that the heart contracts in a period of one minute.

Types of Oximeters

- **Pulse Oximeter as a part of an anesthetic machine**
- **A portable desktop unit**
- **A finger/ mobile pulse oximeter**


98
67
38
6.0

- A pulse oximeter can detect hypoxia (too little oxygen to fulfill the needs of the brain and body) before the patient shows signs of becoming cyanotic (bluish discoloration of the skin and the mucous membranes due to not enough oxygen in the blood)

- Pulse oximeters may be used in patients:

a) Undergoing surgical procedure under general anesthesia

b) Undergoing surgical procedure under conscious sedation

c) Emergency situations like loss of consciousness, Trauma etc

d) After surgery during the recovery phase

e) Monitoring the blood oxygen saturation in various Aviation situations

f) Sports applications – e.g. Mountaineering

- Pulse oximeters reading may not be accurate:

A) Reduced peripheral pulsatile blood flow

B) Various congestion (partial obstruction of the veins) of an arm or the leg

C) Bright overhead lights, such as in an operating theatre

D) Shivering or significant, repeated movement of sensor

E) Distinguishing between different forms of hemoglobin, such as carboxy Hb

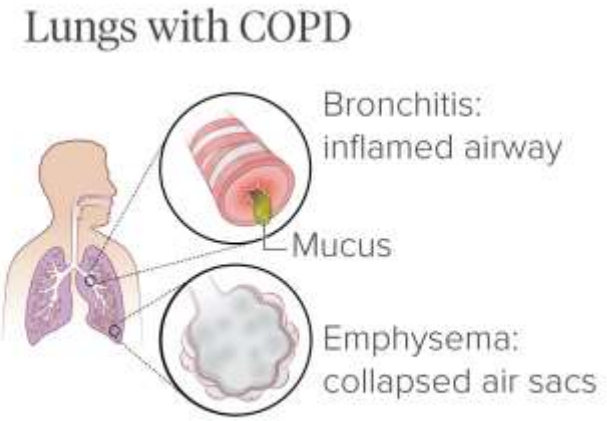
F) Nail varnish may cause falsely low readings with most pulse oximeters, especially the ones with color as blue or black.

- **Following may not affect the Pulse Oximeter reading:**

Normal Reading

- **A fit, healthy person should have an oxygen saturation level between 95% - 99%**

- **Results lower than this, and specially below 90% may be caused by problems including lung diseases, such as COPD, breathing difficulties, cigarette smoking or circulatory problems such as excessive bleeding or blood circulation problem.**

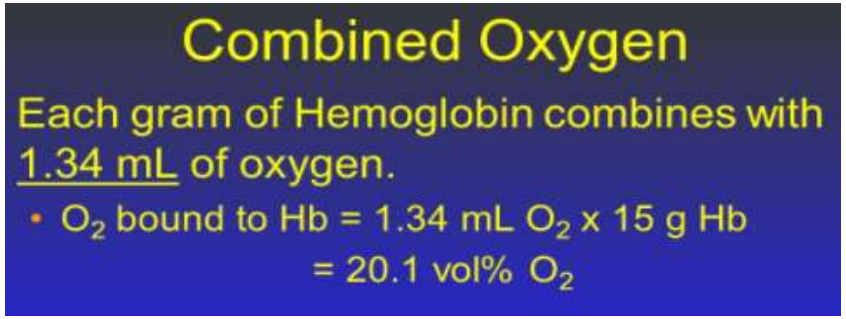


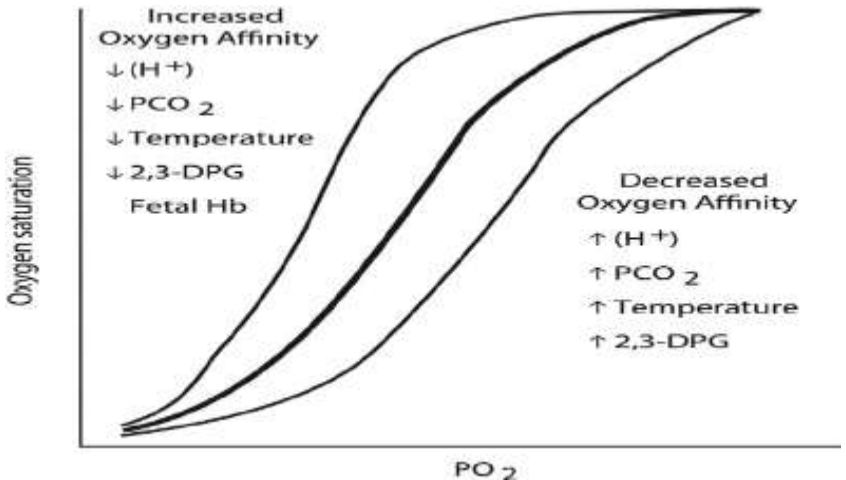
History

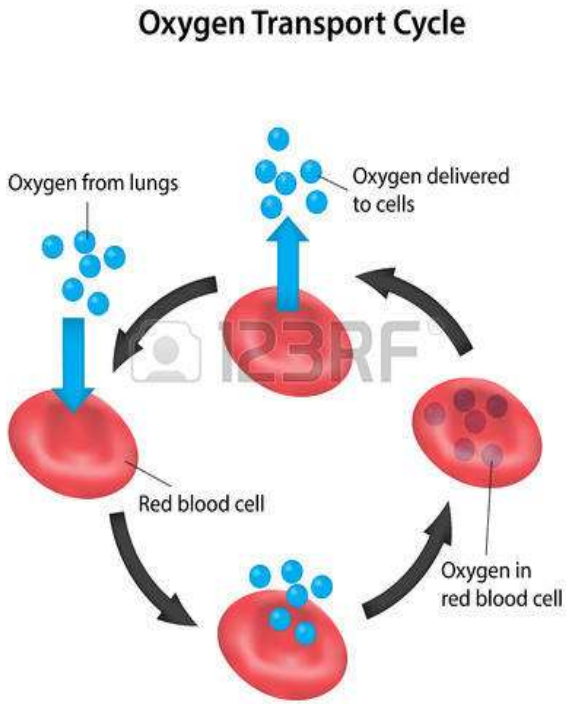
- Karl Matthes – 1935
  - First oximeter to measure 02 saturation
- Subsequent oximeters developed by Hewlett Packard were bulky and expensive ($10,000)
- 1972 – Takuo Aoyagi
  - Pulsatile changes in absorption of red and infra-red light to measure arterial oxygen saturation
- BiOx, Nellcor (started by anesthesiologist Bill New) and Novametrix began manufacturing in 1980's
- 1987 – ASA recommends inclusion of pulse oximetry and capnography into operating room as standard of care
  - Prior to this, morbidity and mortality related to hypoxemia estimated at 1/2000 – 1/7000 cases

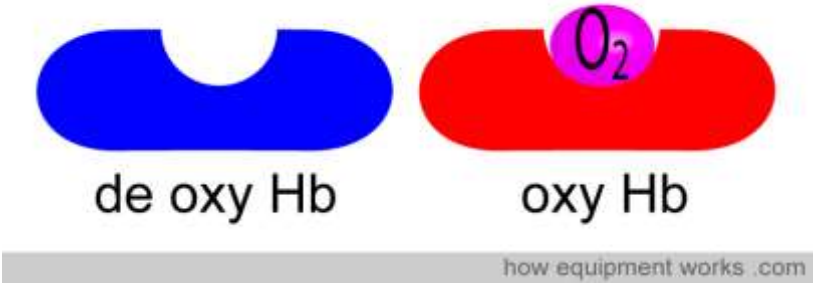
Operating Principle

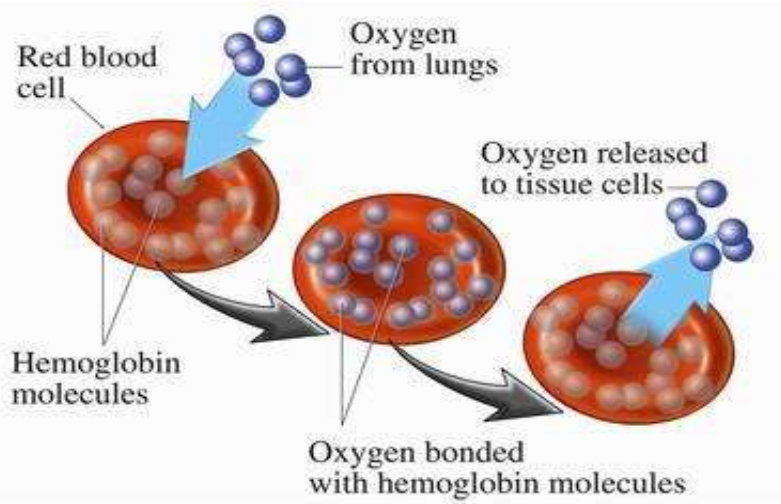
- Oxygenation of Hemoglobin:





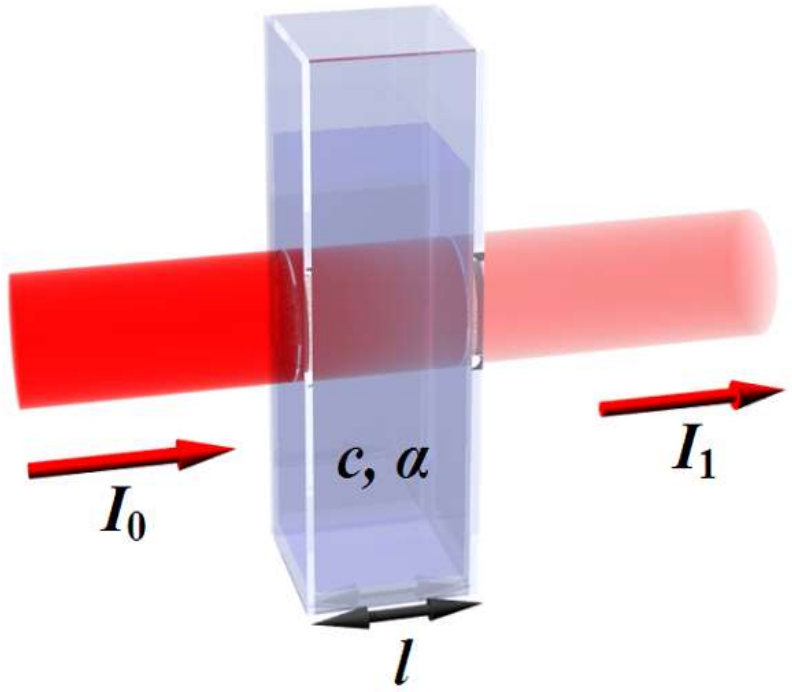






Beer-Lambert Law

- **The combination of both Beer's Law and Lambert's Law**
  - **Beer's Law – the absorption of light is proportional to the concentration of a sample**
  - **Lambert's Law – absorption is proportional to the thickness of a sample**

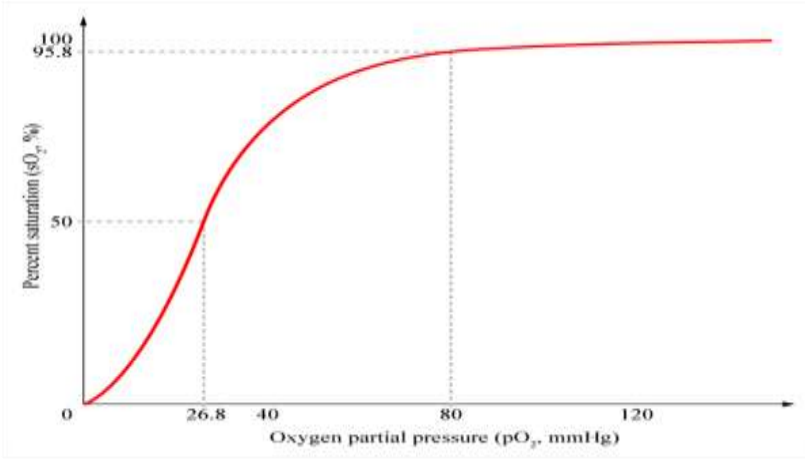


- Hemoglobin has a quaternary structure
  - Most commonly – Hgb A – 2 alpha and 2 beta subunits
  - Infants – Hgb F – 2 alpha and 2 gamma subunits

- Within each of these subunits is a Heme group with a bound Iron atom
  - Fe^{2+} can bind oxygen. Upon binding oxygen, Fe^{2+} is oxidized to Fe^{3+} (methemoglobin), which can not bind to oxygen

- Upon binding a molecule of oxygen, hemoglobin undergoes a conformational change
  - This change enables further oxygen molecules to be bound more easily

- This conformational change makes oxygen binding a cooperative process, and is responsible for the shape of the oxygen-hemoglobin saturation curve



- Pulse oximetry is based on the differential absorption of light by oxyhemoglobin and deoxyhemoglobin

- The oxygenated hemoglobin allows red light to transmit through and absorbs more infrared light while the deoxygenated hemoglobin allows infrared to transmit through and absorbs more red light

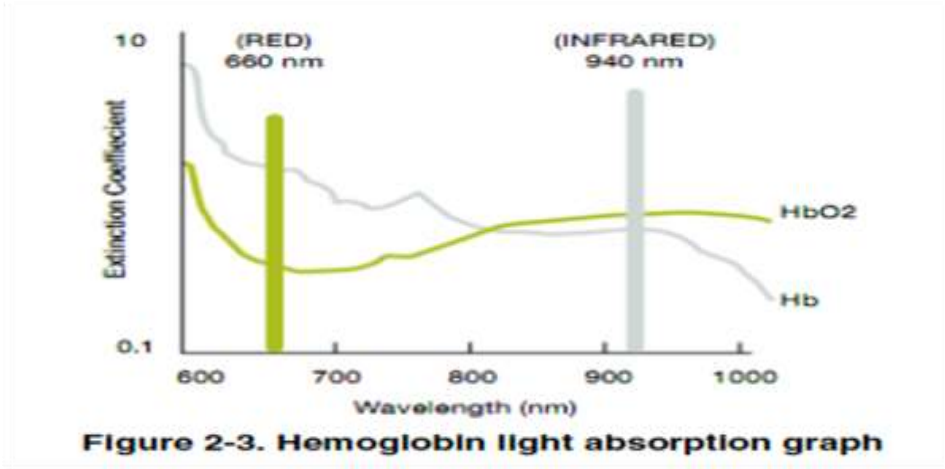
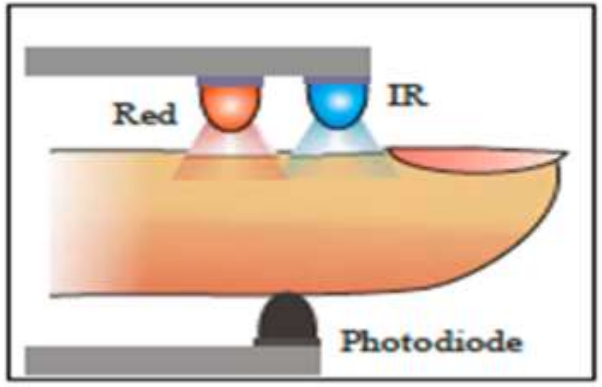


Figure 2-3. Hemoglobin light absorption graph

- A photodetector in the sensor measures unabsorbed light from the LEDs



- The resulting signal is inverted and resembles the diagram below

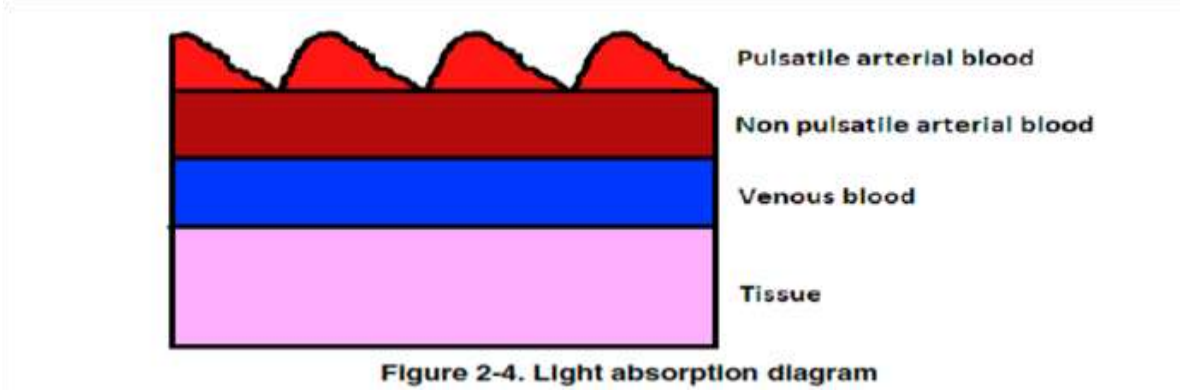
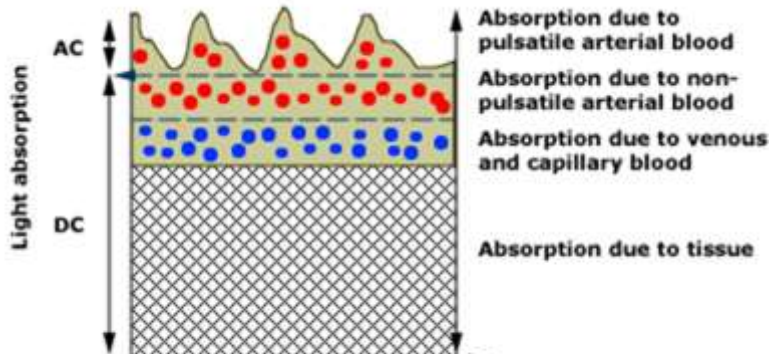
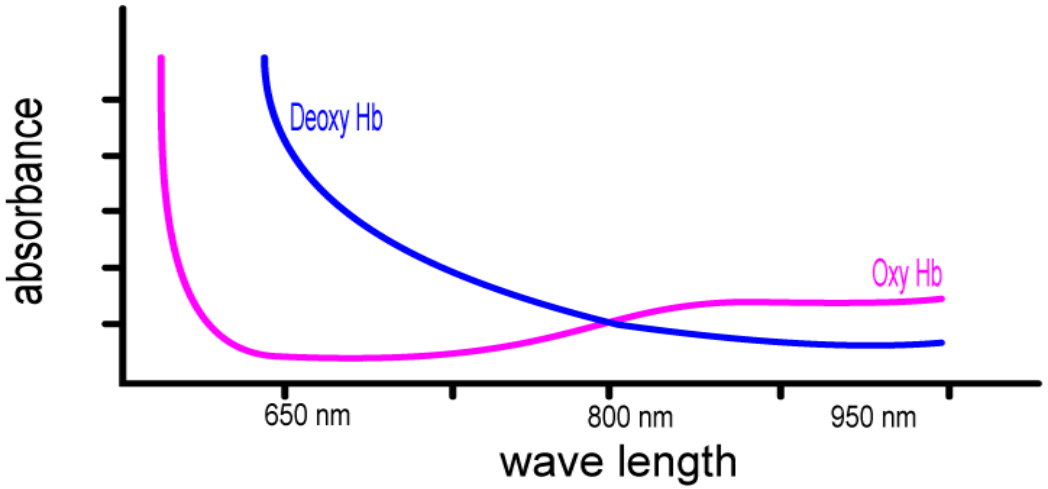


Figure 2-4. Light absorption diagram

- At each site, there are constant light absorbers present
  - Tissue, venous blood and non pulsatile arterial blood
- Surge in arterial blood with each heartbeat results in more light absorbed.
- So the troughs of lower light absorption are subtracted from the peaks, leaving only arterial bloods light absorption being measured
  - Hence “pulse oximetry”





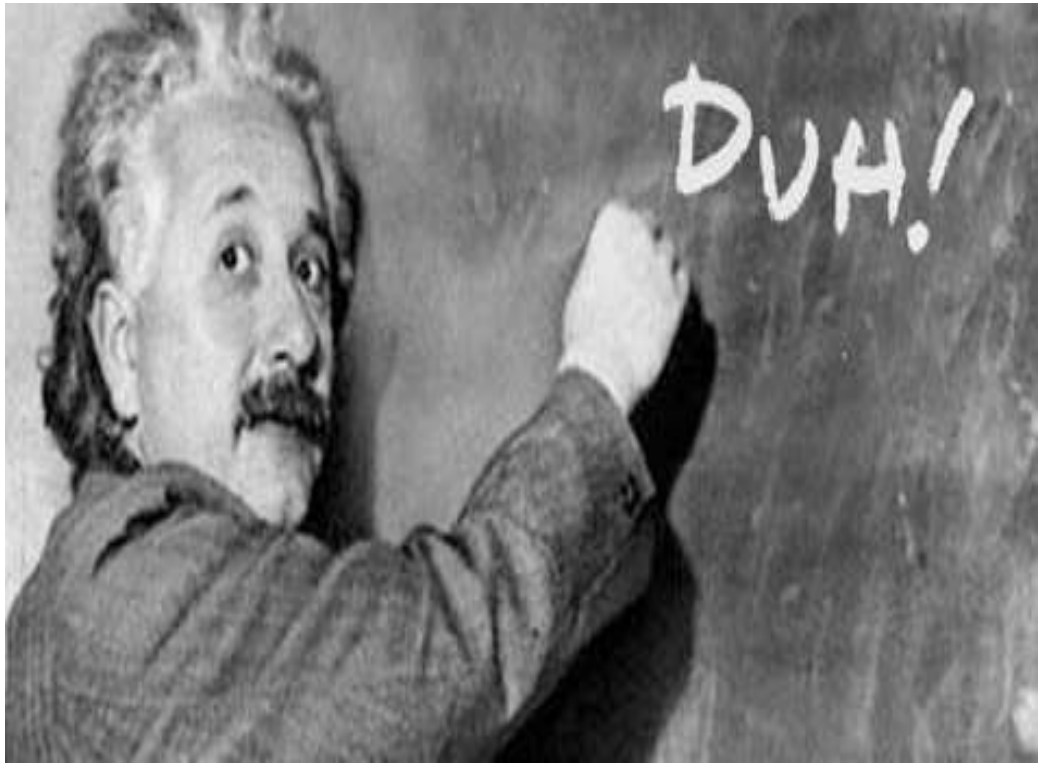
- After the photodetector, the Red/Infrared ratio is calculated

  - This is compared to an algorithm that is specific to each company/device and is based on measurements obtained in healthy volunteers

  - This ratio corresponds to SpO_2
    - 0.5 is approx 100%
    - 1 is approx 85%
    - 2 is approx 0%

Uses

Arterial oxygenation, and, because the variation in light absorption is proportional to the volume of arterial blood with each heart beat, it can be used to estimate volume status (with some computational help)



Sources of Error

- **Strength of Arterial Pulse**
  - **Any factor that reduces arterial pulsations will reduce the ability of the instrument to obtain and analyze the signal**
    - **Hypothermia**
    - **Hypotension**
    - **Vasopressor use**

- **Body Movement**
  - **Extraneous movements can cause intermittent changes in absorbance**
    - **Shivering**
    - **Parkinsonian tremors**

- **Dyshemoglobinemias**
  - **Carboxyhemoglobin**
    - **CO binds to heme competitively with 250 times the affinity of oxygen**
    - **COHgb has same absorption pattern of 660nm light as O2Hgb**
    - **Readings are artificially high**
- **Methemoglobin**
    - **Describes the oxidized form of hemoglobin (Fe^{3+})**
    - **Methemoglobin absorbs as much 660nm red light as it does the 940nm infrared**
    - **Sats approach 85%**
      - **Falsely low at high SpO2, falsely high at low SpO2**

- Methylene Blue, indigo carmine, indocyanin green
  - Cause drop in SpO2

- Color Interference
  - Pulse oximetry not affected by skin color
  - Is affected by artificial or opaque nail finishes that may interfere with transmission of light

- Physical Factors
  - Electrocautery
    - Interferes with signal
  - BP Cuff
    - Don’t place it on the same arm (and forget…)
  - High intensity light
    - Can interfere with signal
      - (make sure the probe is covered)

- Venous Pulsations
  - Secondary to AV fistulas

- Saturations below 80% are inferred, and not based on measurement
  - The R/IR ratio and its correlation to oxygen saturation is based on measurements made on healthy volunteers
    - Only a genocidal IRB would allow for measurements of both to be made at sats < 70%

Q1.

- If a patient's saturation is extremely low, what are your immediate actions?

Check Airways, Breathing and Circulation [ABC]

Q2.

- An elderly patient is admitted with pneumonia and has a pulse oximetry reading of 75% breathing air. With oxygen 6L / min, saturation improves to 85%. What are the implications of this oximetry reading?

The patient is severely hypoxic [Lack of Oxygen]

“INCREASE OXYGEN LEVELS”

Q3.

- What happens to the pulse oximeter reading of a patient immediately after a cardiac arrest?

The pulse would be lost (causing the alarm to sound)

And the saturations will decrease

Q4.

- What happens to the Pulse Oximeter reading of a patient immediately after a respiratory arrest?

The saturations decrease until cardiac arrest occurs

THANK YOU

for your undivided attention… ☺