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Pulse Oximetry

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Disclosure

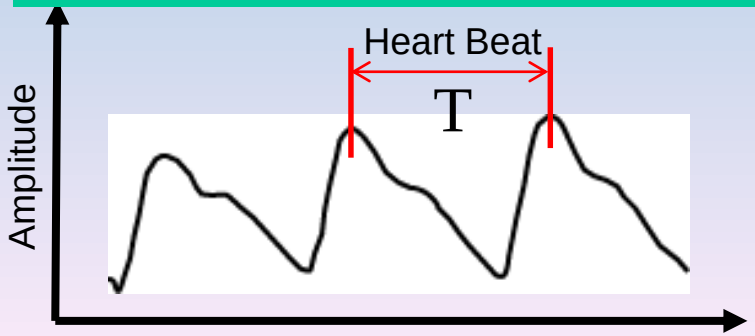
I have no actual or potential conflict of interest in relation to this program and presentation.

What is a Pulse Oximeter ?

A device that measures blood oxygen saturation and pulse rate noninvasively

$$S_pO_2\,(\%) \equiv \frac{[HbO_2]}{[Hb]+[HbO_2]} \times 100$$

Photoplethysmogram (PPG)



&

$$\text{Pulse Rate} = \frac{1}{T}$$

Pulse oximeters are commonly employed in nearly all hospital areas where patients are at risk of developing hypoxemia

- Anesthesiology
- Emergency Room
- Ambulances
- Surgery
- ICU
- Neonatology
- Respiratory Care
- Intrapartum Monitoring
- Nursing Homes
- Home

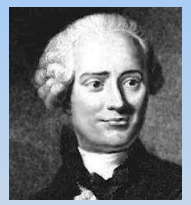
Background

- Appeared in the early 1980's
- Gained overnight popularity
- Revolutionized clinical practice
- No other electronic monitoring device has found widespread use in the operating room more quickly than the pulse oximeter
- By 1987, became the standard of care for the administration of a general anesthetic in the USA
- Transformed monitoring hypoxemia from a crude and imprecise visual color assessment into a reliable, quick, noninvasive and objective measurement

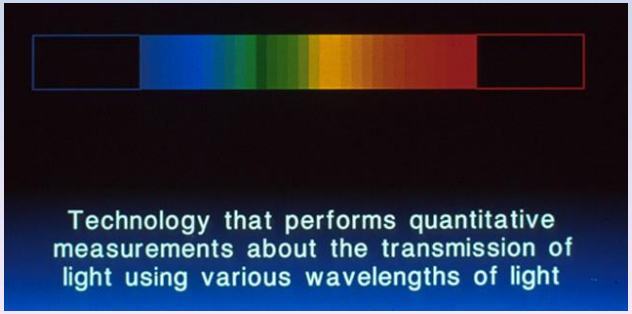
HISTORICAL PERSPECTIVE

Like most modern medical devices, pulse oximeters represent advancements in technology and a culmination of years of knowledge in basic and clinical sciences gained by the trial and failures of numerous researchers from around the world.

1700-1800



The science behind this amazing feat can be traced back to the Swiss scientist Johann Lambert and the German physicist August Beer (the fathers of modern spectrophotometry) who discovered that the amount of light transmitted through a solution varies based on the concentration of solute. Practically applying this idea was much more difficult…. !

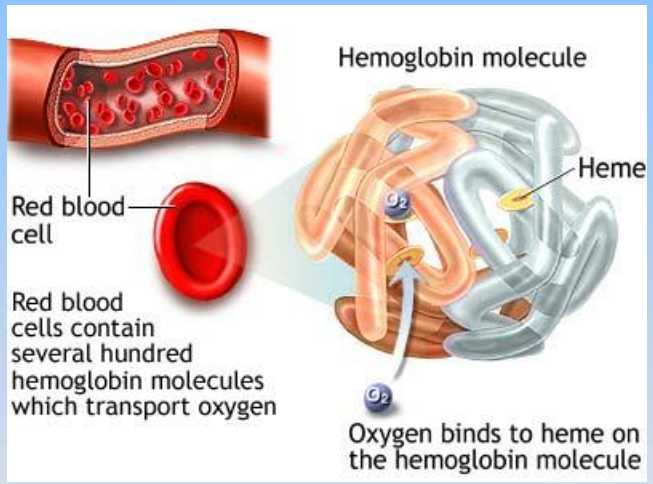


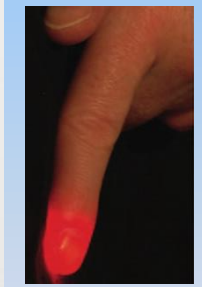
HISTORICAL PERSPECTIVE

1700-1800

1864

George Stokes discovered that hemoglobin is the oxygen carrier in blood.





Cyanosis

Blood depleted of O_2 appears purple/blue

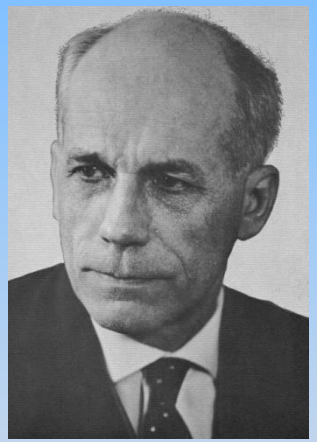
Blood rich in O_2 appears bright red

HISTORICAL PERSPECTIVE

1700-1800

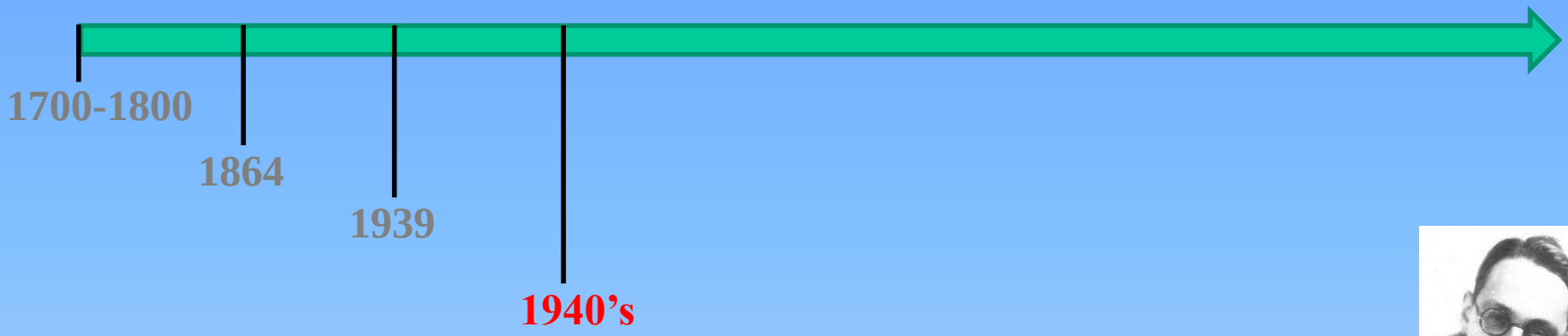
1864

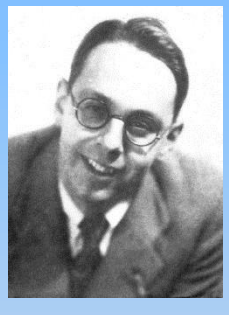
1939



Karl Matthes, a German physician, made a device that showed that oxyhemoglobin saturation could be measured in the **ear**….But, in practice the device functioned poorly, as it was **difficult to calibrate** and absolute values could not be obtained *in vivo*, although it **could follow trends**.

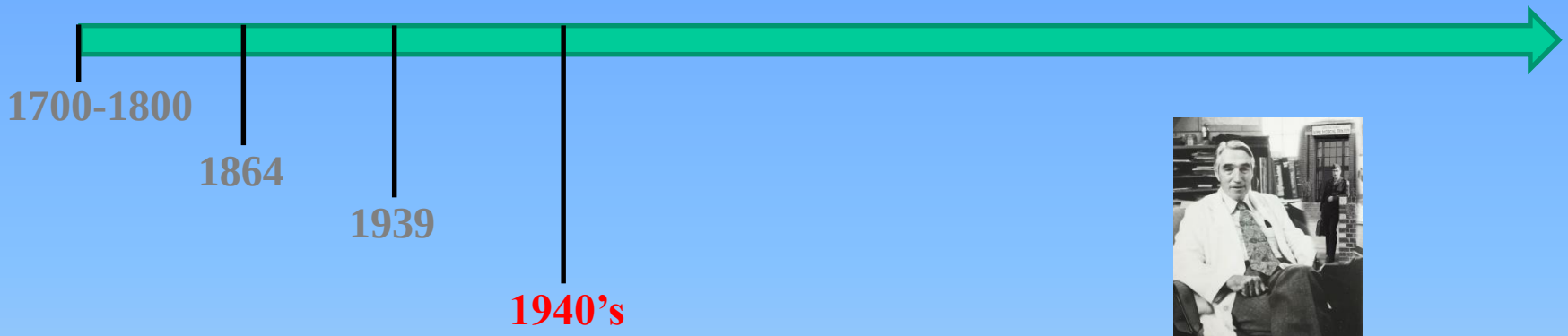
HISTORICAL PERSPECTIVE



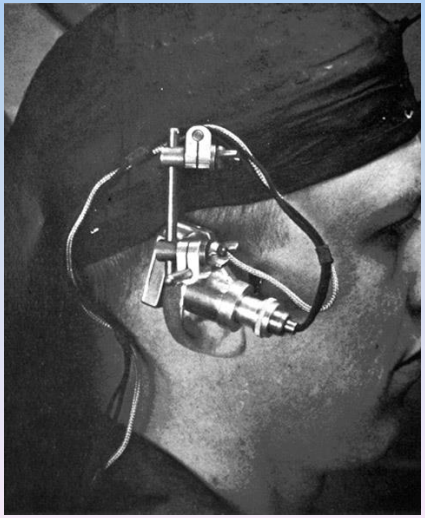


American physiologist Glenn Millikan made an **ear oximeter** to alert pilots during World War II who flew higher than their enemies to avoid detection became **hypoxic** without cockpit pressurization, lost consciousness, and crashed. The ear oximeter performed poorly, because…..

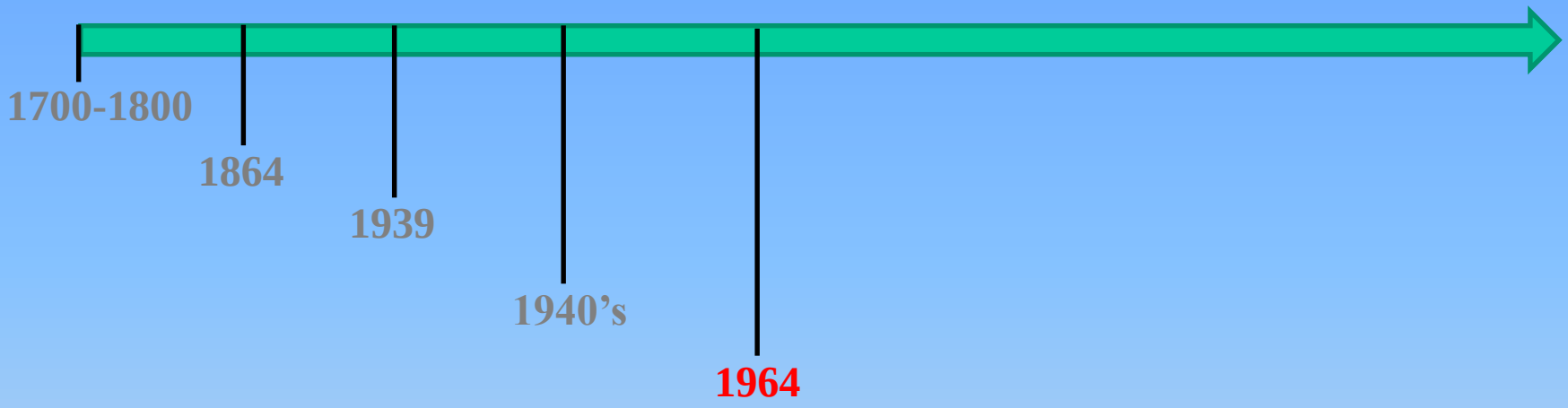
HISTORICAL PERSPECTIVE



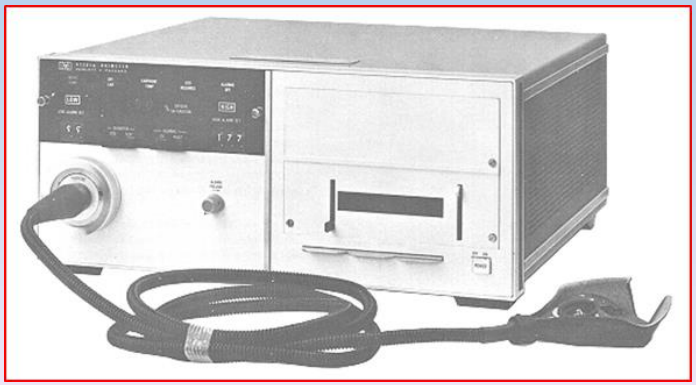
This idea was made more practically feasible when **Earl Wood** at the Mayo clinic used the combination of an **ear oximeter** and pneumatic pressure to squeeze the blood from the ear pinna to obtain a more accurate reading.



HISTORICAL PERSPECTIVE

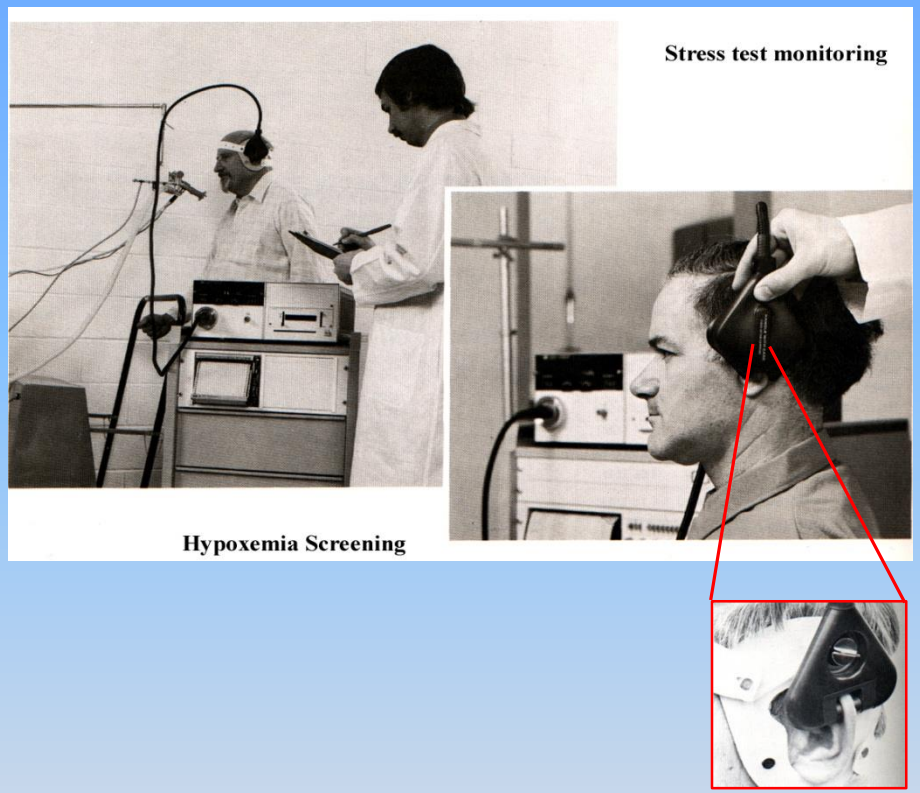


Robert Shaw, a San Francisco surgeon, developed the first **absolute reading ear oximeter** by using 8 wavelengths of light.



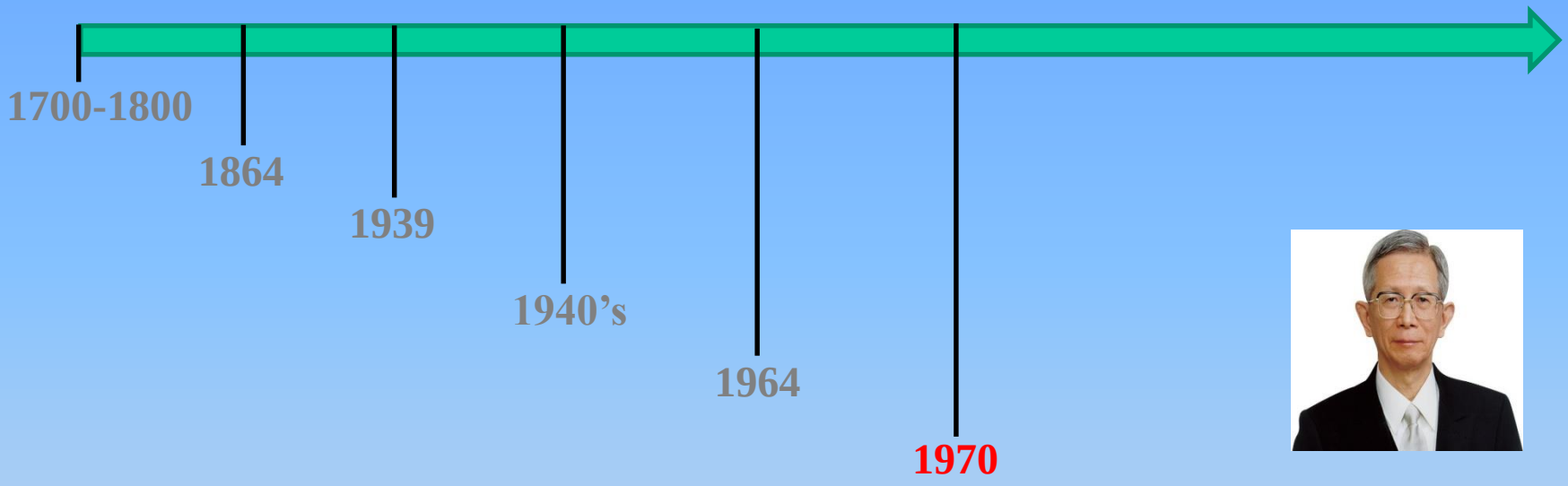
Commercialized by Hewlett-Packard in 1970

HEWLETT-PACKARD EAR OXIMETER



- ✓ **The unit was used primary in sleep and pulmonary function laboratories, but….it was:**
  - **Costly ($10,000)**
  - **Heavy (35 lbs)**
  - **Very bulky**
  - **Clumsy**

HISTORICAL PERSPECTIVE



Serendipitously, **Takuo Aoyagi**, a Japanese electrical engineer working at Nihon Kohden Corporation, was trying to measure the dilution of a dye for purposes of measuring **cardiac output** in the **ear**. He kept having difficulty because of the **arterial blood pulsations**.

HISTORICAL PERSPECTIVE

1700-1800

1864

1939

1940's

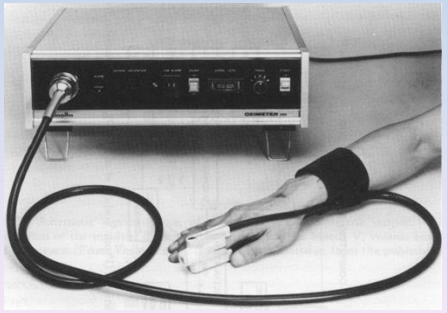
1964

1970

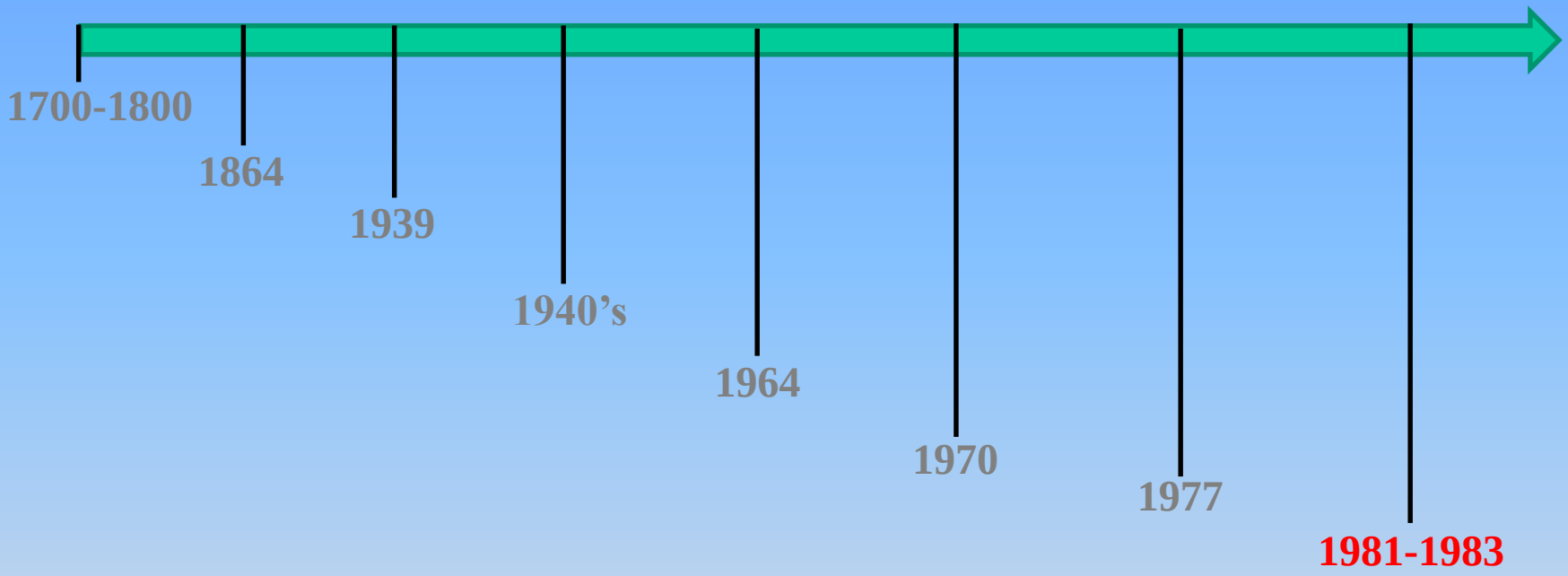
1977

Despite his incredible ingenuity…..

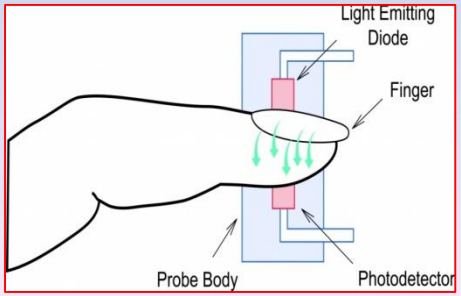
Unfortunately, the business Aoyagi worked for did not recognize the potential of his invention, and the Minolta company developed the OXIMET with a **fingertip probe** and **fiber-optic cables**.



HISTORICAL PERSPECTIVE



Soon thereafter, Biox Technology and Nellcor commercialized a **similar** finger pulse oximeter by taking advantage of **advancements in semiconductor technology**.



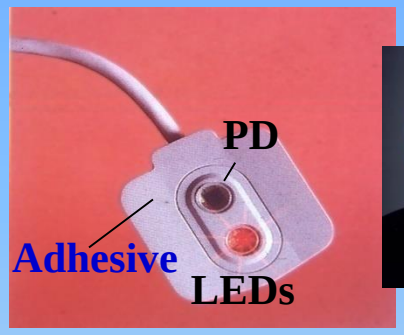
Clinical Relevance of Pulse Oximetry

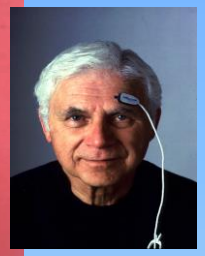
Provides essential information on the sufficiency of O_2 *supply* in the body

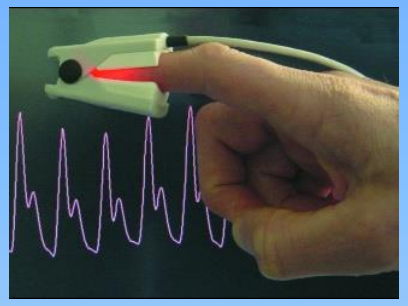
- **The motivation for pulse oximetry began in the 1970s when malpractice insurance for anesthesiologists was rapidly climbing.**
- **Monitoring the respiratory condition of a patient during surgery in those days involved drawing arterial blood and sending the sample to the lab for blood gas analysis.**
- **Under typical circumstances, test results would arrive back in ~15 minutes.**
- **Between such intermittent measurements of blood gases, much could and did happen to a patient under anesthesia.**

Commercial Products

Mature technology

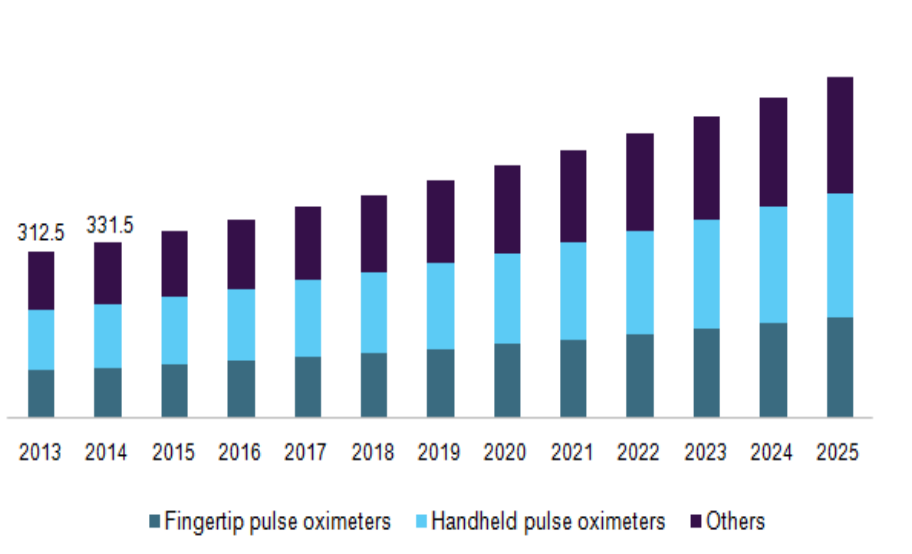






Market Size

The worldwide market for pulse oximetry is over a billion US dollars.



U.S. pulse oximeters market projections by type, 2013 - 2025 (USD Million)

The global market size is projected to grow by ~**6%** over the forecast period. The huge **burden of healthcare costs** push patients to opt for home care. This boosts the demand for remote patient monitoring devices, which results in increased demand for pulse oximeters.

http://www.grandviewresearch.com/industry-analysis/pulse-oximeter-market

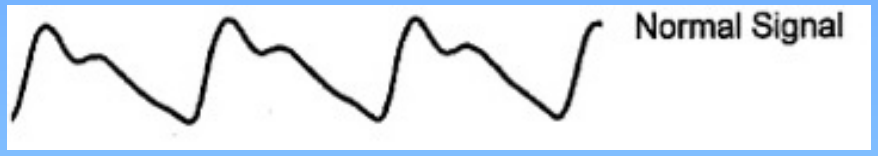
Undisputed Advantages

Disruptive Technology…..!

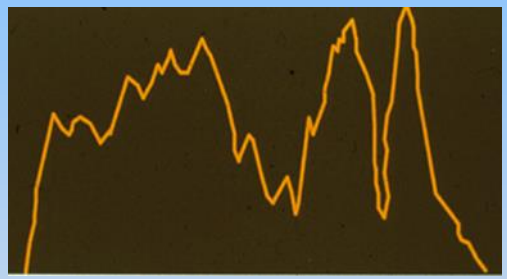
- **Noninvasive**
- **Compact**
- **Low-cost, affordable**
- **Provide early warning of hypoxemia**
- **Increased patient safety**
- **Dramatic drop in anesthesia death rate**
- **Reduces caregiver workload**

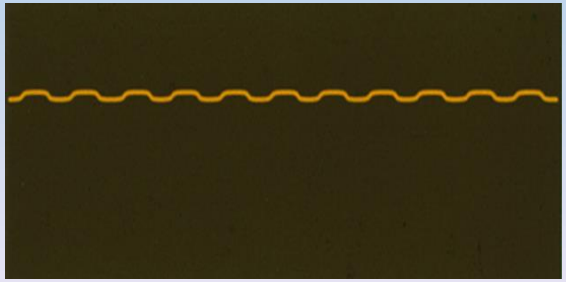
Technological Challenges

Like most medical devices, the pulse oximeter is not perfect!



- **Motion artifacts (shivering, restlessness)**
- **Low perfusion (hypothermia, vasoconstriction, hypovolemia)**
- **Dyshemoglobinaemias (HbCO, Met Hb)**
- **Anaemia**
- **Intravenous dyes**
- **Pigmented skin**
- **Nail polish**
- **Abnormal pulses (venous pulsations)**
- **Low saturations (accuracy below 80% SpO_2)**
- **Ambient light**





Recent Advances

- **New generation of pulse oximeters can provide accurate measurements in challenging situations (e.g. low perfusion, presence of motion artifacts, low S_pO_2)**
- **Recent advances have focused on the morphological analysis of the PPG waveform**
- **The complex PPG waveform is used to analyze new parameters that may have significant impacts on future clinical practice**
- **Pleth Variability Index (PVI): variability of the PPG amplitude due to respiration; thought to be a surrogate measure of intravascular volume**
- **Perfusion Index (PI): reflects peripheral vasomotor tone. Low PI suggests peripheral vasoconstriction (or severe hypovolemia) and high PI suggests vasodilation**

Thank You !