FYS 4250

Lecture 4



Case 4



- 19 year old female, healthy and takes no regular medications except for contraceptive pills. No significant medical history, father has been diagnosed with diabetes type II

Case 4



- The patient used Trinordiol, no other medication. Friends sent her to hospital as they could see she was getting “blue”, at the time of admission to hospital she was at a good general condition, no dyspnea, blood pressure 140/80 mmHg and HR 130/min regular, core temperature of 37.0 degrees celcius, respiratory rate of 30 /min, no extraordinary events prior to the incident. Electrolytes, creatinine, infection parameters and liver parameters were all normal.

- What is wrong with her?

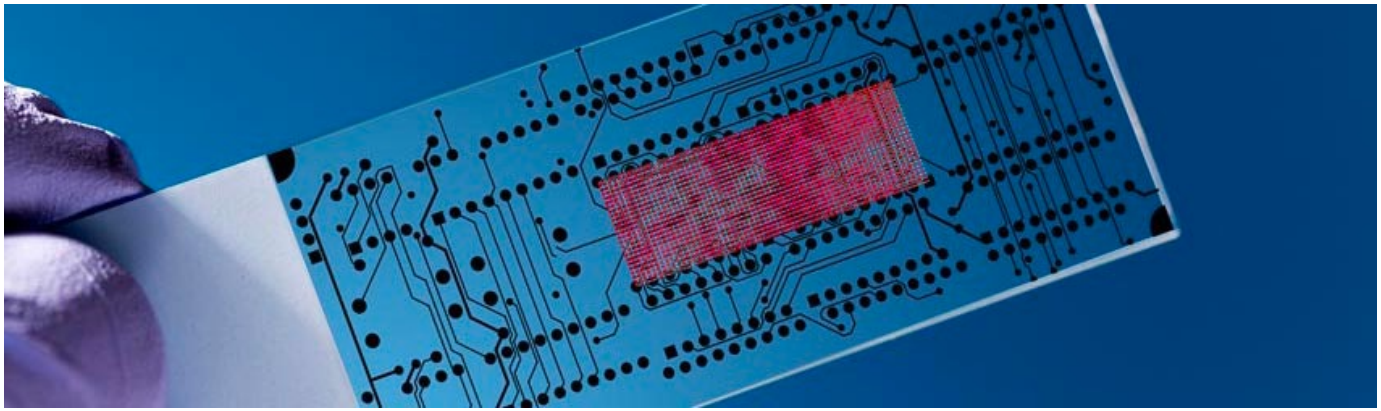
Organ systems



- An **organ** is a group of cells which forms tissues that work together for a specific function or task (e.g. the brain)
- An **organ system** is a group organs that work together in order to perform a specific function or task (e.g. the nervous system)
- **Functional status** of an organ system can be determined by measuring the chemical input/output analytes of the cell

-> Most tests performed in hospitals are analyzing different chemistries of the human body

Chemical biosensors



https://www.microdrop.de/biosensor.html

Blood tests: Hot topic

businessinsider.com/theranos-founder-elizabeth-holmes-and-sunny-balwani-charged-with-wire-fraud-2018-6?r=US&IR=T

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From Silicon Valley superstar to facing jail time on fraud charges, here's where Theranos founder Elizabeth Holmes is now

Lydia Ramsey Mar. 19, 2019, 9:56 AM



Former Theranos founder and CEO Elizabeth Holmes leaves Federal Court on January 14, 2019 in San Jose, California. Justin Sullivan/Getty Images

- **Theranos founder Elizabeth Holmes and former Theranos president Sunny Balwani have been charged with nine counts of wire fraud and two counts of conspiracy to commit wire fraud.**
- **The charges stem from allegations that the two engaged in a scheme to defraud investors and a separate scheme to defraud doctors and patients while at the blood-testing company, the Department of Justice said in June 2018.**

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Vis alle

Oxyhemoglobin dissosiation curve

Binding of oxygen to Hb depends on partial pressure og PO2 in blood, and temperature and pH (affinity)

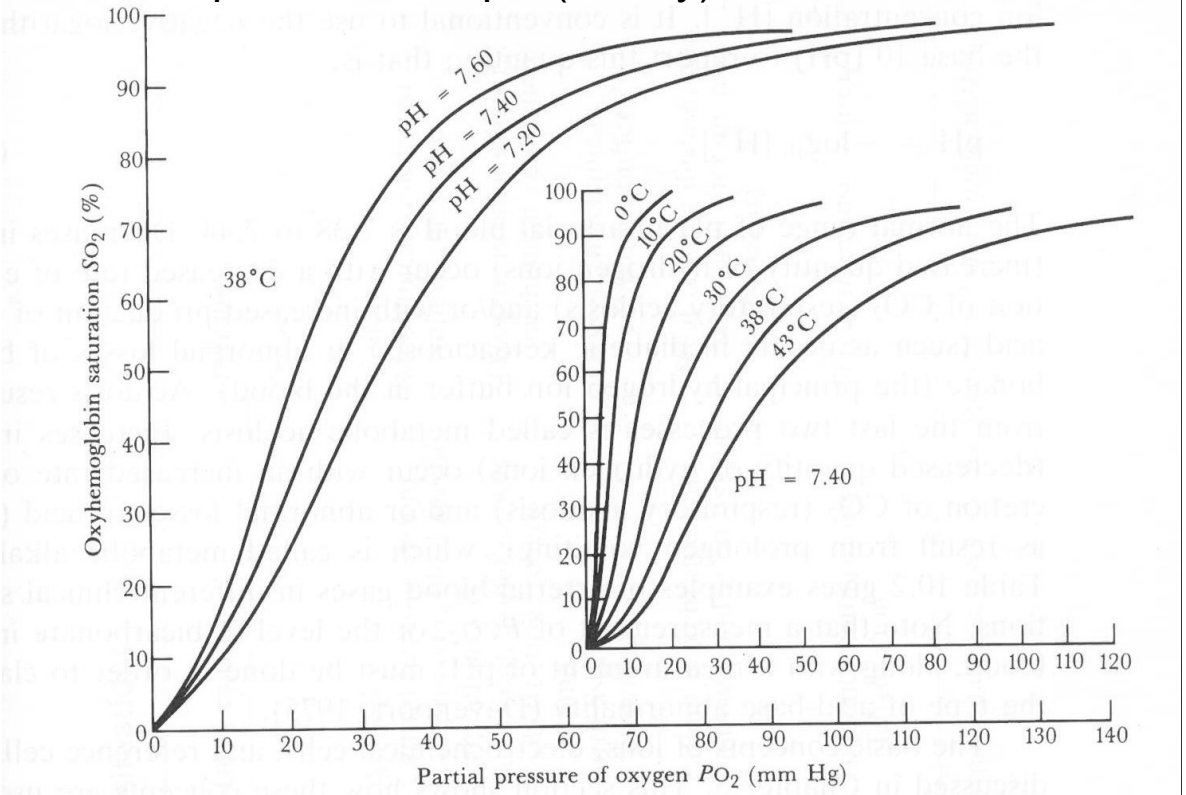


Figure 10.1 The oxyhemoglobin dissociation curve, showing the effect of pH and temperature on the relationship between SO_2 and PO_2.

Examples

454

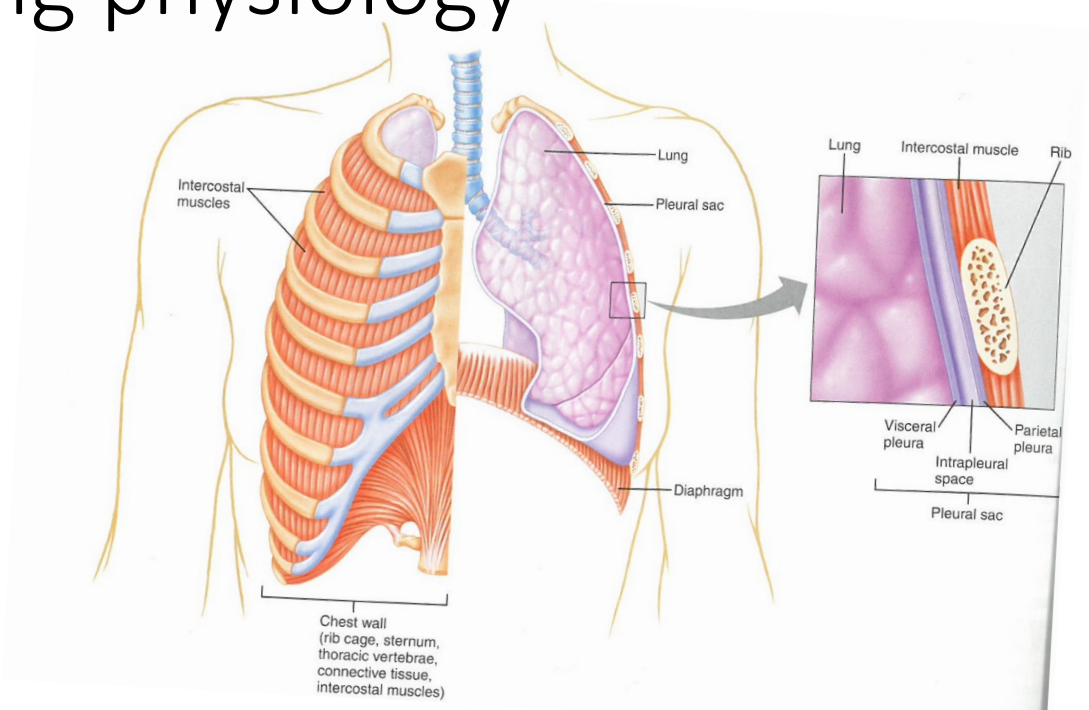
Table 10.2 Examples of Arterial Blood Gases in Different Clinical Situations

Example	PCO_2, mm Hg	pH	PO_2, mm Hg	Interpretation	Likely Causes	Therapy
1	40 ± 3	7.40 ± 0.03	90 ± 5	Normal blood gas		None
2	44 ± 3	7.37 ± 0.03	88 ± 5	Normal blood gas while asleep		
3	22	7.57	106	Hyperventilation	Anxiety	None
4	68	7.10	58	Hypoventilation	Central nervous system depression; blockage of upper airway	Mechanical ventilation; relieve the cause
5	58	7.21	39	Hypoventilation and hypoxemia	Pneumonia; small-airway obstruction; severe asthma	Oxygen; bronchodilators; mechanical ventilation
6	61	6.99	29	Combined respiratory and metabolic acidosis and hypoxemia	Birth asphyxia; near-drowning	Oxygen; mechanical ventilation; buffers?
7	60	7.37	106	Chronic respiratory acidosis with metabolic compensation; patient is receiving supplemental oxygen	Patient has chronic lung disease and is on oxygen	Treat chronic disease; no additional therapy may be necessary
8	29	7.31	106	Metabolic acidosis with respiratory compensation	Diabetic; ketoacidosis; dehydration	Treat the cause; buffers?

SOURCE: B. G. Nickerson and F. Monaco, "Carbon dioxide electrodes, arterial and transcutaneous," in J. G. Webster (ed.), Encyclopedia of Medical Devices and Instrumentation. New York: Wiley, 1988, pp. 564–569.

SO2(%) = ([HbO2]/[Total Hb]) x 100
98% of oxygen carried with Hb
2% dissolved in plasma

Lung physiology

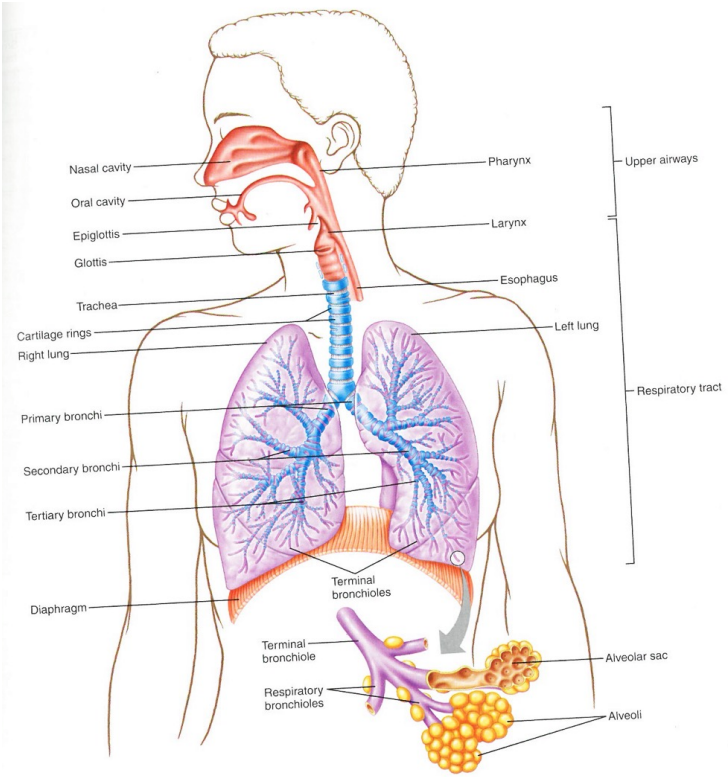


The ribs, sternum, thoracic vertebrae, connective tissue and muscles makes the chest wall

The pressure gradient between the alveoli and the outside air (atmosphere) makes the air flow in or out of the lungs

Source: Principles of human physiology, Germann/Stanfield

Lung physiology



Anatomy of the upper airways

Source: Principles of human physiology, Germann/Stanfield

Lung physiology

TOOLBOX

BOYLE'S LAW AND THE IDEAL GAS LAW

A fundamental relationship governing the behavior of gases is the *ideal gas law*, which is expressed as follows:

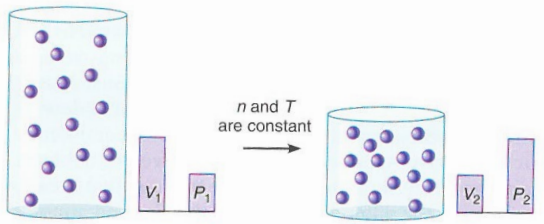
$$PV = nRT$$

where P is the gas pressure (in units of atmospheres; 1 atm = 760 mm Hg), V is the volume in which the gas is contained (liters), n is the quantity of gas (moles), R is the universal gas constant (0.083 liter-atm/mole-K), and T is the absolute temperature (kelvins, K). This equation can be rearranged such that pressure is given in terms of the other variables, as follows:

$$P = nRT/V$$

Given a fixed quantity of gas in a container at a given temperature, n and T are both constant, and the pressure is inversely proportional to the volume of the container: $P \propto 1/V$. This is Boyle's law, illustrated in the figure. If instead the volume of the container is fixed but the quantity of gas is allowed to vary, the quantity RT/V becomes constant. Under these conditions, the pressure is proportional to the number of molecules in the container: $P \propto n$.

When we consider why gases exert pressure, we can see why the pressure varies with the number of gas molecules in a container. Gas molecules are normally in a state of constant thermal motion. Gas molecules inside a container continually collide with the wall and rebound off it. Every collision exerts a certain amount of force on the wall. The *pressure* is the total force exerted by all such collisions divided by the surface area of the wall (force per unit area). If the number of molecules is held constant but the volume of the container decreases, the density of molecules increases, so any given area of the wall experiences more collisions per second, and the pressure is higher. If more molecules are added to a container with a fixed volume, the same thing happens: Molecules are more densely spaced, which increases the number of collisions per unit area of wall, which raises the pressure.



Container 1: $V_1 = 2$ $P_1 = 1$ Container 2: $V_2 = 1$ $P_2 = 2$

Source: Principles of human physiology, Germann/Stanfield

Lung physiology

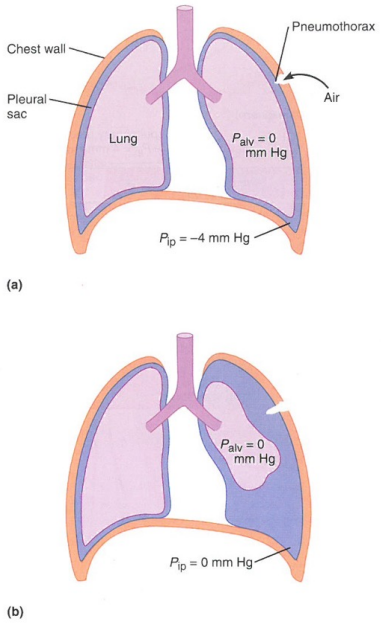


Figure 17.9 Pneumothorax. (a) Normal intrapleural pressure at rest is −4 mm Hg. Air entering the intrapleural space through a hole in the chest wall creates pneumothorax. (b) As a consequence of pneumothorax, intrapleural pressure equilibrates with atmospheric pressure. Without the negative force of intrapleural pressure drawing the lung outward, the lung collapses due to elastic recoil forces.

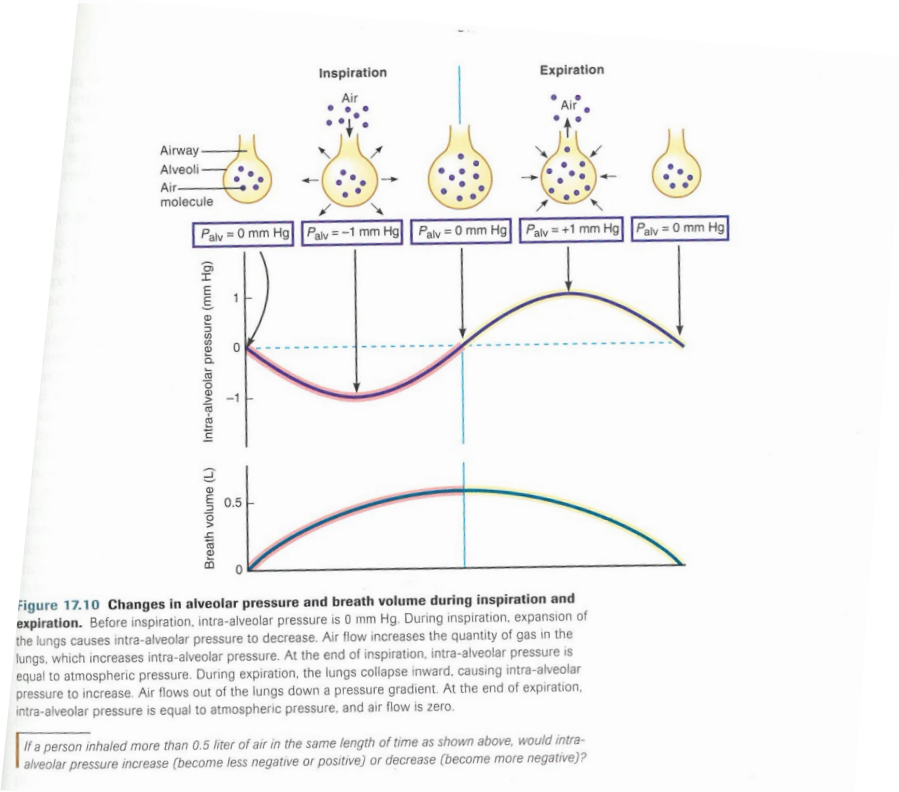


Figure 17.10 Changes in alveolar pressure and breath volume during inspiration and expiration. Before inspiration, intra-alveolar pressure is 0 mm Hg. During inspiration, expansion of the lungs causes intra-alveolar pressure to decrease. Air flow increases the quantity of gas in the lungs, which increases intra-alveolar pressure. At the end of inspiration, intra-alveolar pressure is equal to atmospheric pressure. During expiration, the lungs collapse inward, causing intra-alveolar pressure to increase. Air flows out of the lungs down a pressure gradient. At the end of expiration, intra-alveolar pressure is equal to atmospheric pressure, and air flow is zero.

If a person inhaled more than 0.5 liter of air in the same length of time as shown above, would intra-alveolar pressure increase (become less negative or positive) or decrease (become more negative)?

Source: Principles of human physiology, Germann/Stanfield

Exercise

10:59 30.08 • Jenny-Linn Lohne

FLERE FÅR BEHANDLING I TRYKKTANK

Fem personer som var på grottefesten i Oslo er behandlet i trykktank og følges opp for noe mer alvorlig skade.

– En god del vil vi ha til observasjon det neste døgnet. De som har blitt behandlet i trykktank kan det tenkes at blir hos oss litt til, sier kommunikasjonsrådgiver Anders Bayer ved Oslo universitetssykehus.



NRK: Flere har fått hjerne-skader etter grottefest

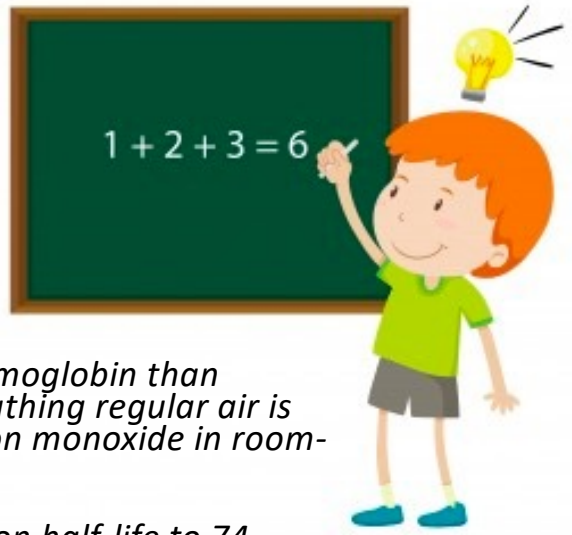
Form groups of 2 or 3 students, and discuss:

a. Why was the patients after the cave-rave treated in a pressure chamber after the carbon monoxide poisoning?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answers



Carbon monoxide binds 230-300 times stronger to hemoglobin than oxygen, half-life of carbon monoxide in the blood breathing regular air is more than 5 hours (it takes a day to remove the carbon monoxide in room-air).

Giving the patient 100% oxygen reduces the elimination half-life to 74 minutes = more than 5 hours for a moderately exposed patient to reach acceptible levels. With hyperbar treatment (2.5 bar) the half-life is reduced to about 20 minutes, because the elevated alveolar pressure will increase the exchange rate of carbon monoxide replacing them with oxygen, and more oxygen is also dissolved in plasma

https://www.verywellhealth.com/carbon-monoxide-poisoning-treatment-4161055

pH = -log(10)[H+] normal range <7.38, 7.44>

The pH electrode

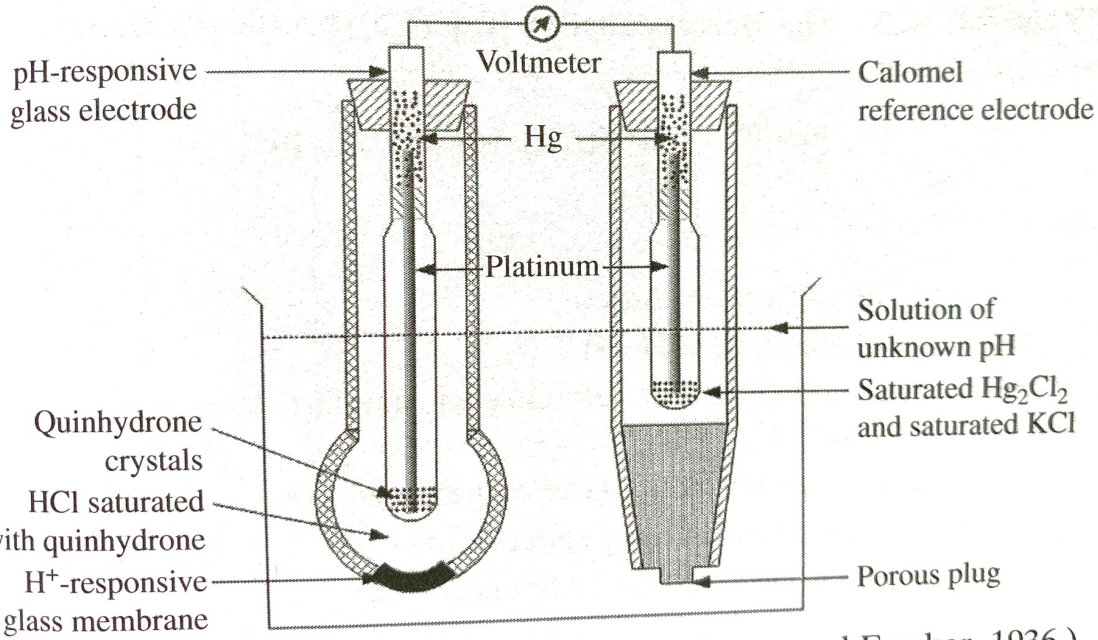


Figure 10.2 pH electrode (Adapted from Beckman and Fracker, 1936.)

pH electrode

- Electrochemical cell (Potentiometric measurement)
- pH = -log(10)[H+] normal range <7.38, 7.44>
- Decreased pH = respiratory acidosis (metabolic/respiratoric)
- Generates an electrical potential when solutions of differing pH are placed on the two sides of the membrane. (Reacts only to specific ion)
- Approach of Hydrogen outside -> positive charges inside ionic solution
- 60 mV pr pH unit (Nernst equation) -> pH range of only 0.06 units -> measure changes of 0.1 mV
- Known pH inside (HCl)
- Salt bridge to prevent chemical constituents of the specimen from affecting the voltage of the reference electrode
- pH meter -> exremely high input impedance (internal impedance of the pH electrode is in the 10 to 100 Mohm range

pH

Fiberoptic pH sensor

Warning: Hb has a strong affinity for CO, -> optical spectra overlap causing an error

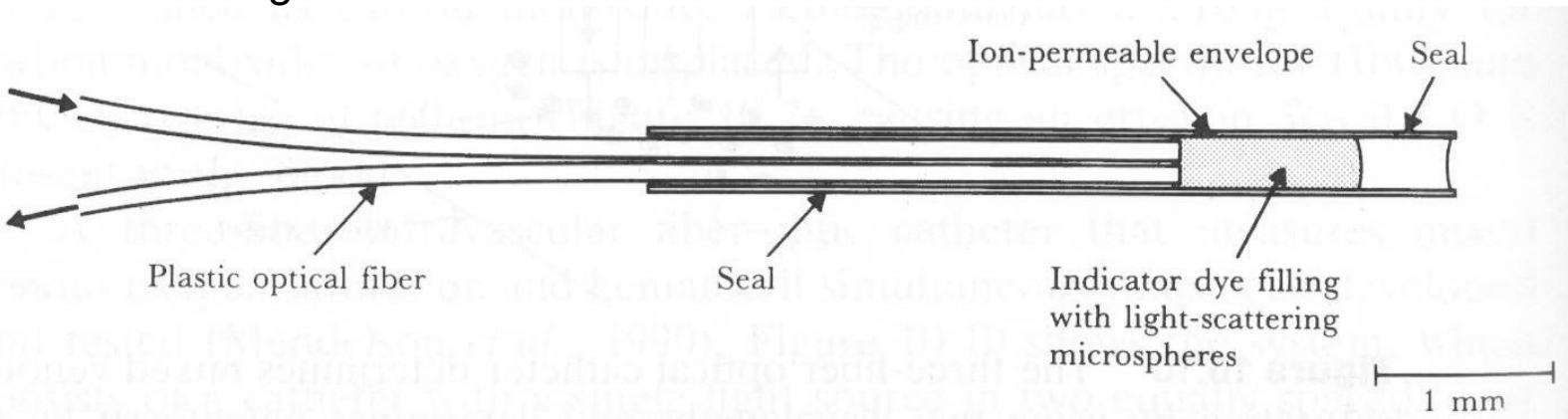


Figure 10.11 A reversible fiber-optic chemical sensor measures light scattered from phenol red indicator dye to yield pH. [From J. I. Peterson, "Optical

The dye needs to be reversible

pH

Wavelength indicating that the optical absorbance peak increases with increasing pH
Ratio of green to red light transmitted through the dye is:

R = k x 10 exp [-C/((10exp -delta) + 1)]

Optical absorbance pH sensitive dyes

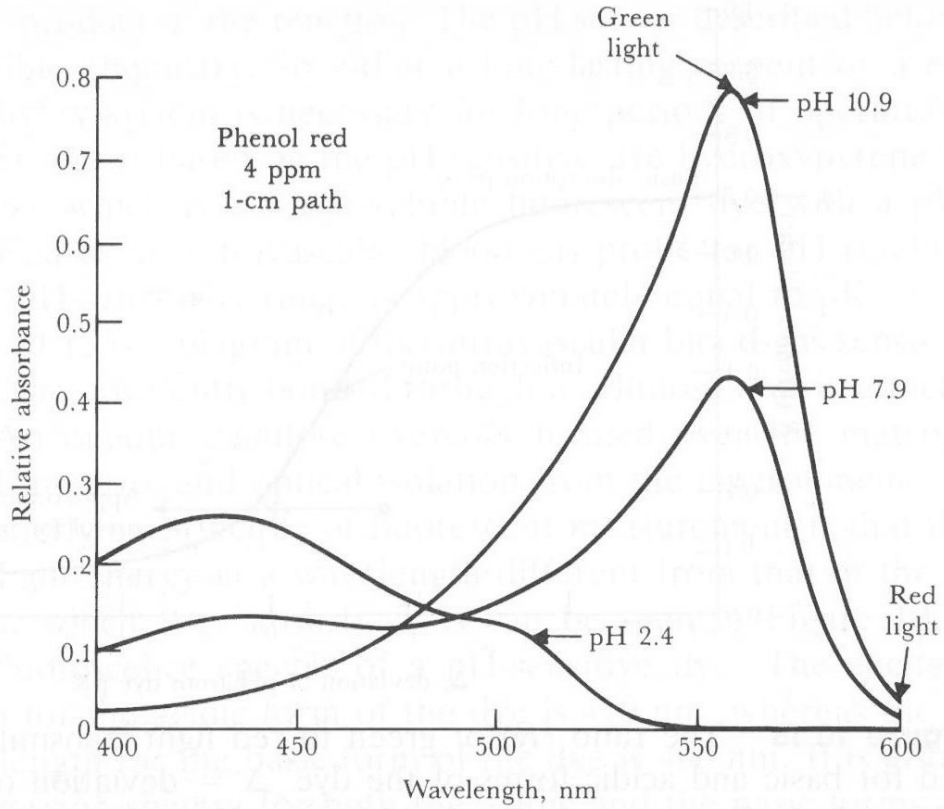


Figure 10.12 The plot of absorbance against wavelength of phenol red (base form) increases with pH for green light but is constant for red light.

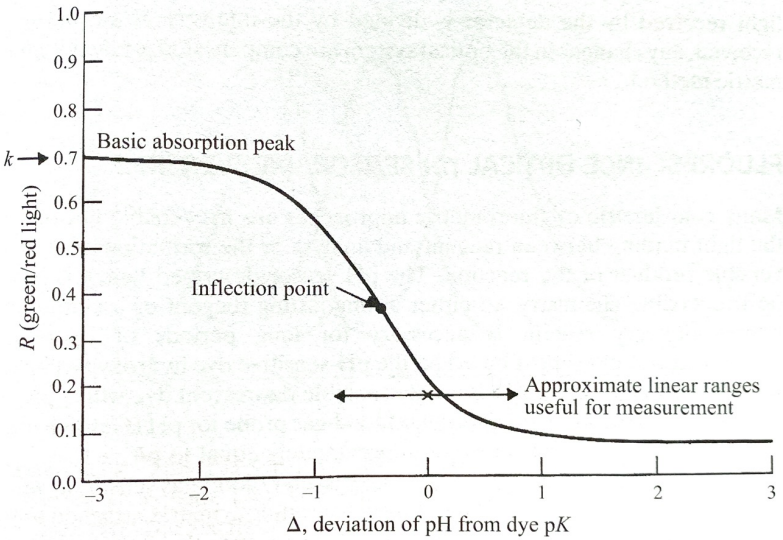


Figure 10.11 The ratio (R) of green to red light transmitted through phenol red for basic and acidic forms of the dye. Δ = deviation of pH from dye pK. (From Peterson, J. I., S. R. Goldstein, and R. V. Fitzgerald, "Fiber-optic pH probe for physiological use." *Anal. Chem.*, 1980, 52, 864–869. Used by permission.)

Ratio between red and green light, green light varies with pH, red light is an isobestic wavelength does not vary = dual beam spectrometer

Irreversible reactions -> long-lasting reagent
Cellulose matrix. Fluorescent dyes emit light energy at a wavelength different from that of the excitation wavelength, which they absorb

pH
Fluorescent dyesensor (irreversible)

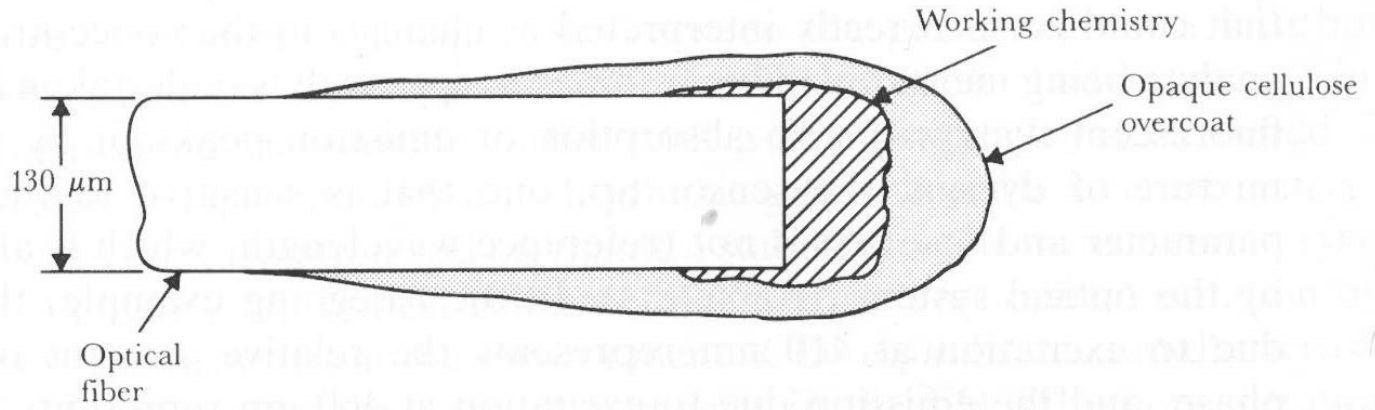


Figure 10.15 A single-fiber intravascular blood-gas sensor excites fluorescent dye at one wavelength and detects emission at a different wavelength. The following modifications are made to the sensor tip:
pH: Chemistry—pH-sensitive dye bound to hydrophilic matrix.
P_{CO_2}: Chemistry—Bicarbonate buffer containing pH-sensitive dye with silicone.
P_{O_2}: Chemistry—Oxygen-sensitive dye in silicone.
(From J. L. Gehrich, D. W. Lübbers, N. Opitz, D. R. Hansmann, W. W. Miller, J. K. Tusa, and M. Yafuso, "Optical fluorescence and its application to an intravascular blood gas monitoring system," *IEEE Trans. Biomed. Eng.*,

pH
pH-sensitive dyes

Because of the separation between excitation and emission wavelengths, use a single optical fiber both for the delivery of light energy and for its reception from that sensore

The dye fluoresces for a shorter period of time = inversely proportional to the pH

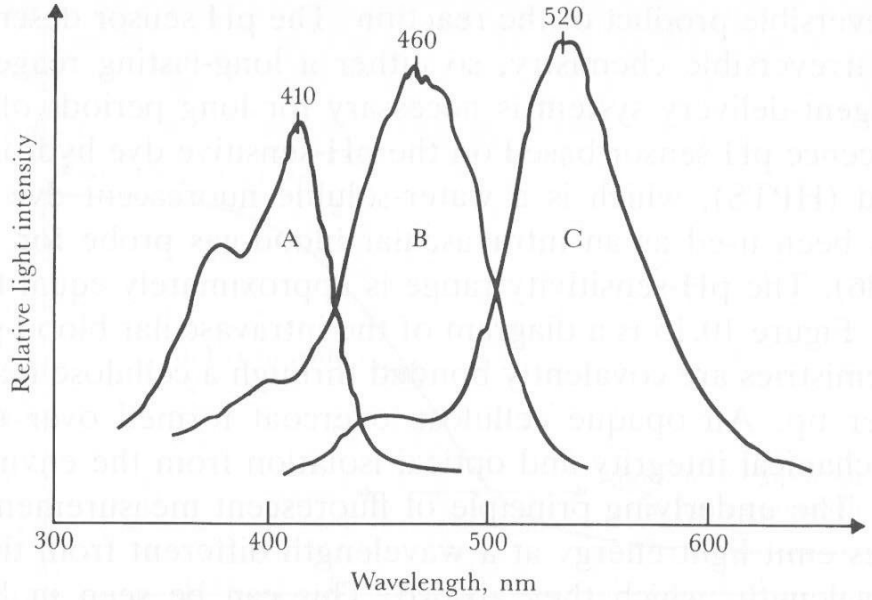


Figure 10.16 This pH-sensitive dye is excited at 410 and 460 nm and fluoresces at 520 nm. (A) The excitation spectrum of the acidic form of the dye; (B) the excitation spectrum of the basic form of the dye; (C) the emission spectrum of the acidic and basic forms of the dye. (From J. L. Gehrich, D. W. Lübbers, N. Opitz, D. R. Hansmann, W. W. Miller, J. K. Tusa, and M. Yafuso, "Optical fluorescence and its application to an intravascular blood gas monitoring system," *IEEE Trans. Biomed. Eng.*, 1986, BME-33, 117–132. Used by permission.)

pH
Ion-sensitive field-effect transistor

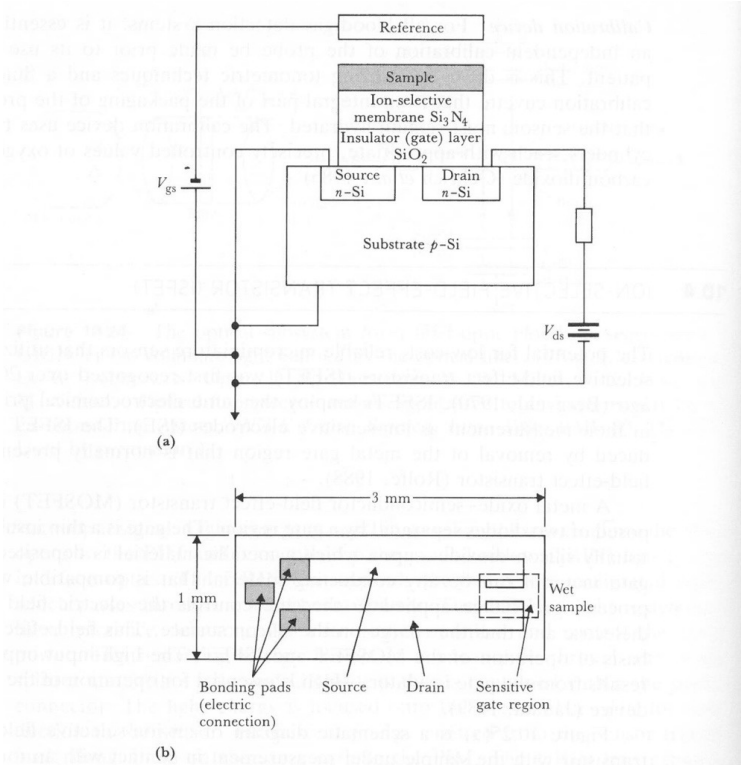


Figure 10.25 (a) In a chemically sensitive field-effect transistor, the ion-selective membrane modulates the current between the source and the drain. (b) A stretched ISFET maximizes the spacing between the "wet" sample region and the electric connections. (Part (b) from P. Rolfe, "*In vivo* chemical sensors for intensive-care monitoring," *Med. Biol. Eng. Comput.*, 1990, 28. Used by permission.)

Ion concentration modulates the current between source and drain

Low cost microminiature sensor (IC)

Small sizes

Low measurement time

Main challenge: Satisfactory encapsulation of the ISFETs to protect electric characteristics. (Will deteriorate as a result of water vapor entering from the environment)

pH
Potassium-sensitive ISFET

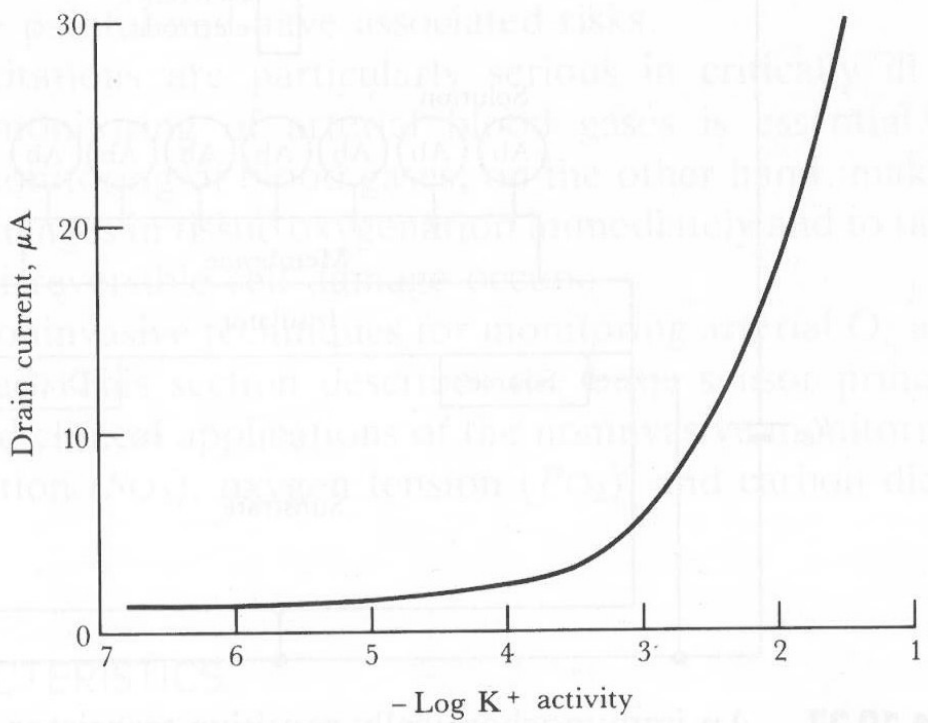


Figure 10.26 Dependence of current on potassium ion activity for a potassium ion–sensitive field-effect transistor.

pH
Multigas fiberoptic sensor

System considerations
Operating temp: 15 to 42 deg C
pH from 6.8 to 7.4
pCO2 from 10 to 100 mmHg
pO2 from 20 to 500 mmHg
Sterilizable and biocompatible
Must not be affected by naturally occurring substances as proteins

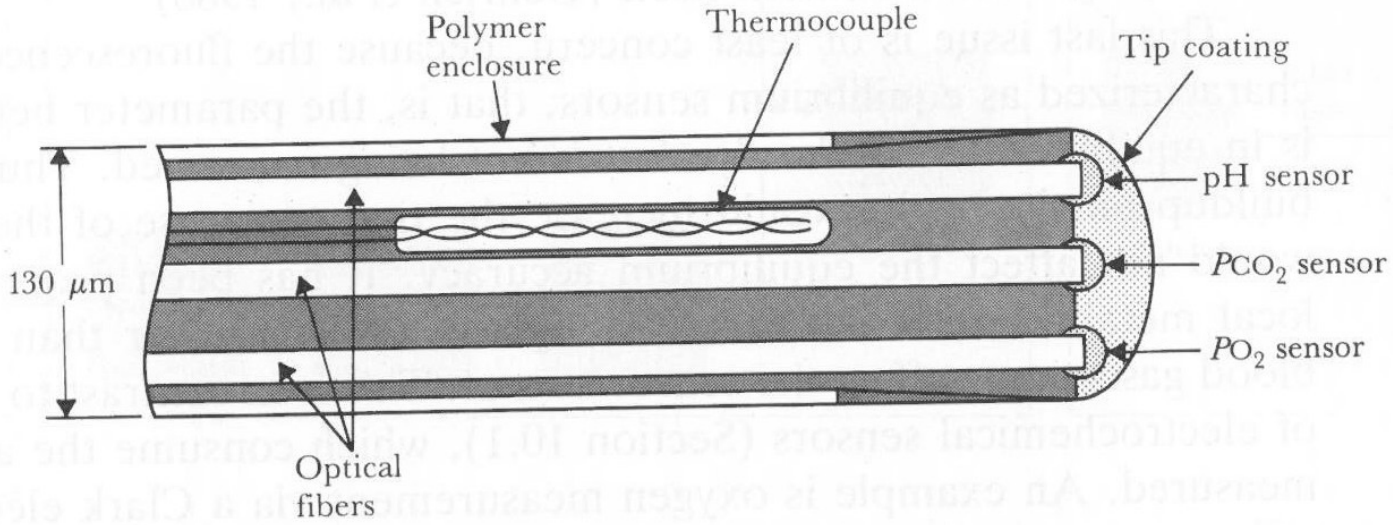


Figure 10.22 An intravascular blood-gas probe measures pH, P_{CO_2}, and P_{O_2} by means of single fiber-optic fluorescent sensors. (From J. L. Gehrich, D. W. Lübbers, N. Opitz, D. R. Hansmann, W. W. Miller, J. K. Tusa, and M. Yafuso, "Optical fluorescence and its application to an intravascular blood gas monitoring system," *IEEE Trans. Biomed. Eng.*, 1986, BME-33, 117–132. Used by permission.)

Exercise

Form groups of 2 or 3 students, and discuss:

a. Explain the different methods of measuring pH in blood

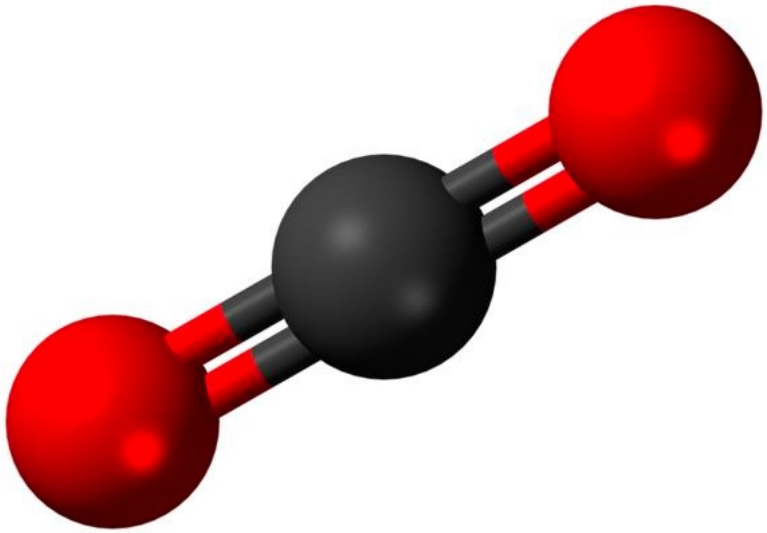
b. What are the main error sources for each?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

pCO_2 measurement

http://edu.hioa.no/kjemifk/atom/



The pCO_2 electrode (Severinghaus)

Relationship between log pCO2 and pH is linear over the range of 1.3 to 12 kPa = range of clinical interest

One specimen chamber and one pH electrode chamber

Only a proportional relationship -> calibrate the instrument before each use

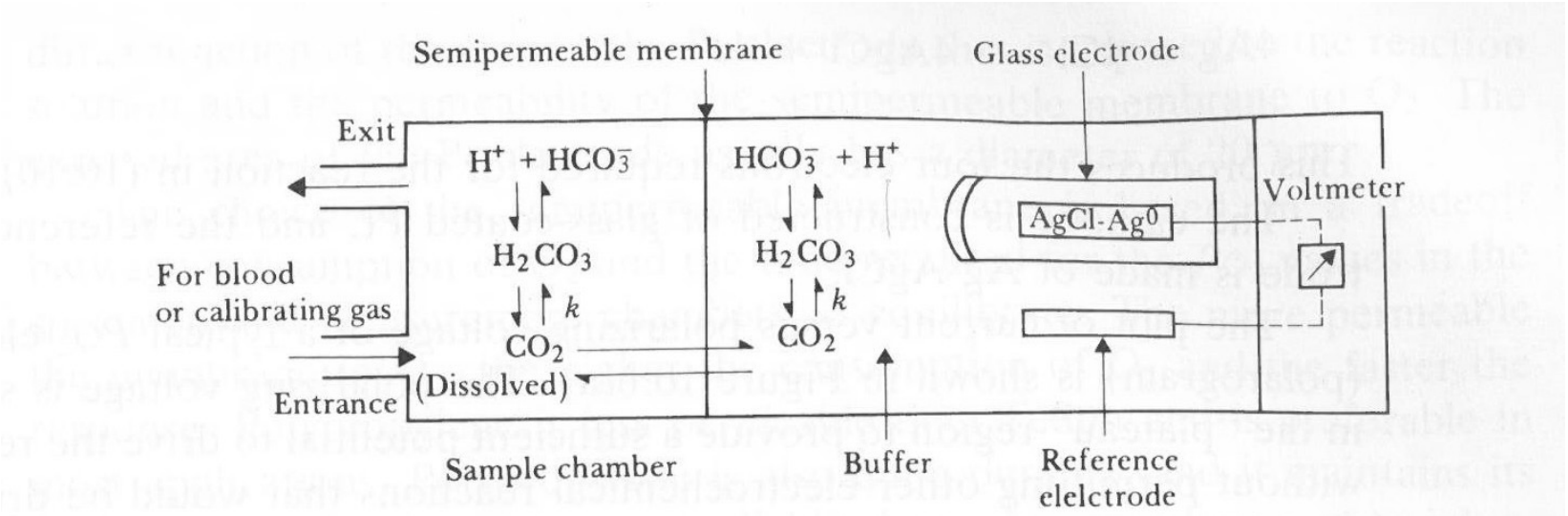
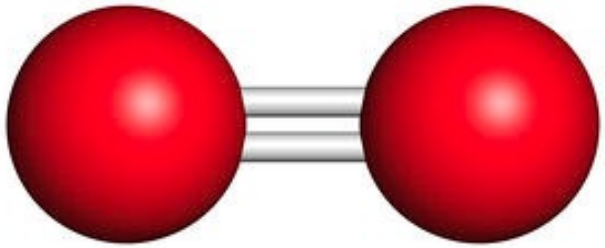


Figure 10.4 P_{CO_2} **electrode** (From R. Hicks, J. R. Schenken, and M. A. Steinrauf, *Laboratory Instrumentation*. Hagerstown, MD: Harper & Row, 1974. Used with permission of C. A. McWhorter.)

pO2 measurement

https://www.canstockphoto.com/elemental-oxygen-o2-molecular-model-13225049.html



Fiberoptic oxygensensor

Blue/green ratio is taken, current-to-voltage converter is used to provide the voltage proportional to the blue and green light

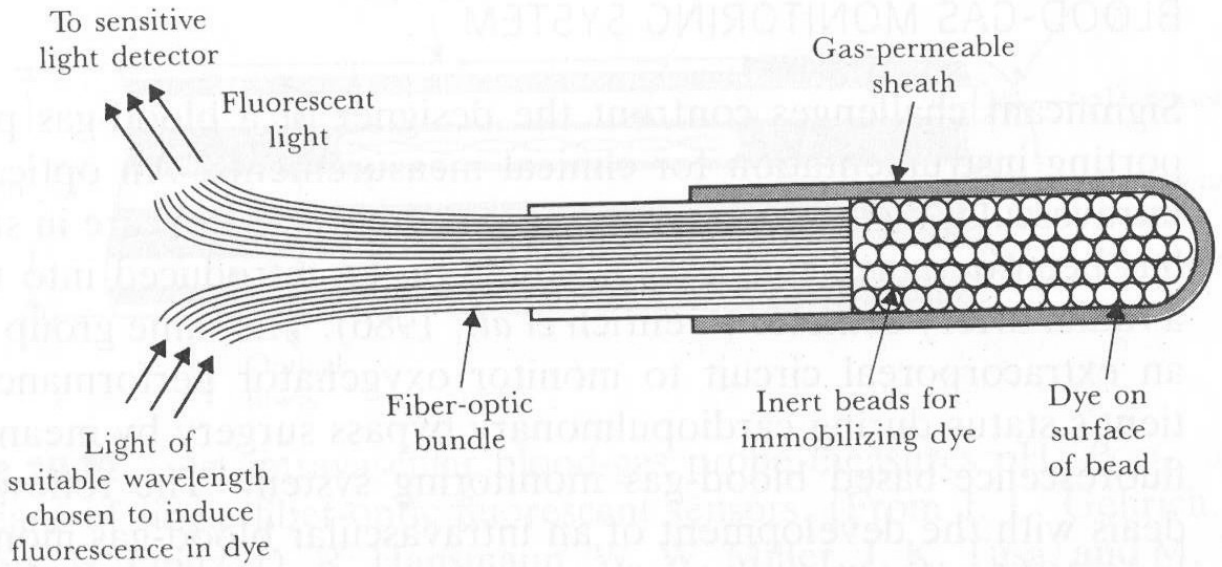


Figure 10.20 In a fiber-optic oxygen sensor, irradiation of dyes causes fluorescence that decreases with P_{O_2}. [From R. Kocache, "Oxygen analyzers," in J. G. Webster (ed.), *Encyclopedia of Medical Devices and Instrumentation*. New York: Wiley, 1988, pp. 2154–2161. Used by permission.]

The pO_2 electrode (Clark)

Oxidation at the reference electrode: 4Ag + 4Cl- -> 4AgCl + 4e-
Reduction at cathode: O2 + 2H2O+4e- ->2H2O2 + 4e- -> 4OH-
4OH- + 4KCl -> 4KOH + 4Cl-

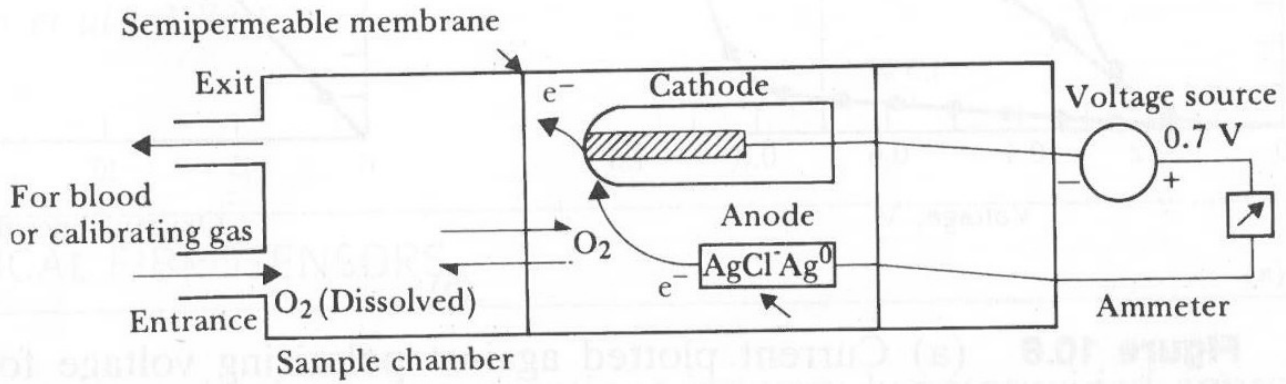


Figure 10.5 P_{O_2} **electrode** (From R. Hicks, J. R. Schenken, and M. A. Steinrauf, *Laboratory Instrumentation*. Hagerstown, MD: Harper & Row, 1974. Used with permission of C. A. McWhorter.)

The relating current is linearly proportional to the number of O2 molecules in solution
PO2 level is zero = background current -> part of the calibration procedure
Consumes O2 - depleting of oxygen near the electrodes - > stirring effect when moved -> have to wait for stagnant equilibrium
Sensitive to temperature

The pO_2 electrode (Clark)

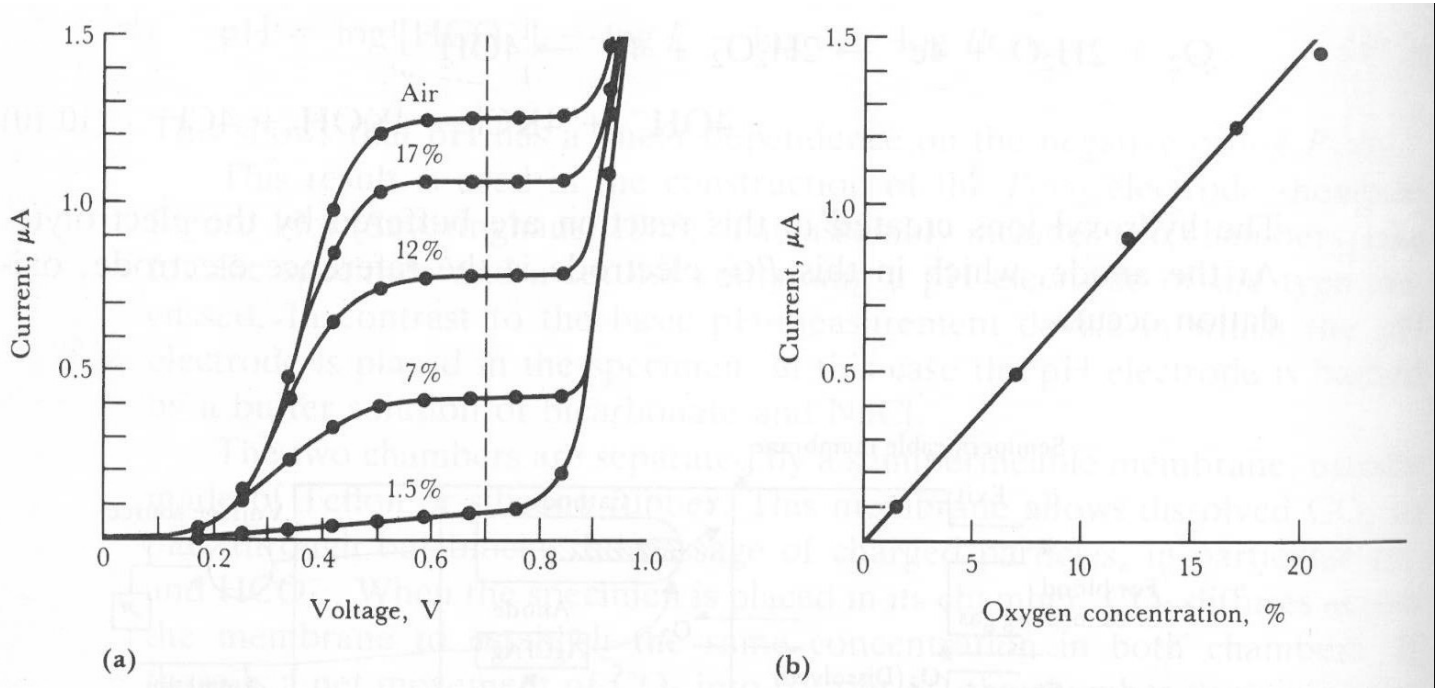


Figure 10.6 (a) Current plotted against polarizing voltage for a typical P_{O_2} electrode for the percents O_2 shown. (b) Electrode operation with a polarizing voltage of 0.68 V gives a linear relationship between current output and percent O_2.

Oxygen-sensitive dyes

Principle of fluorescence or luminescence quenching of oxygen -> energy lost. With O2 present-> transfer of energy to oxygen molecule->competes with energy decay modes ->increased luminescence by increasing loss of energy to oxygen
Irradiated by light at given wavelength -> when oxygen present -> fluorescence is quenched = dye fluoresces for a shorter period of time. (Inversely proportional to the partial pressure of Oxygen in the environment)
Poor SNR for high O2 levels

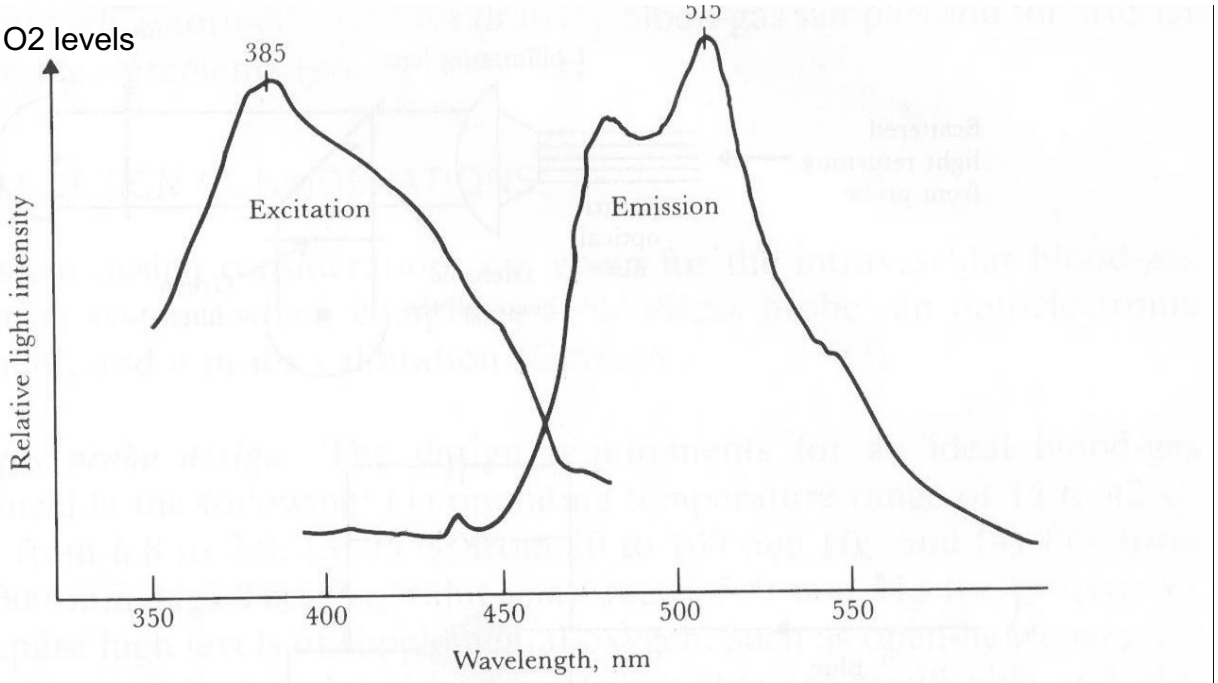


Figure 10.19 The emission spectrum of oxygen-sensitive dye can be separated from the excitation spectrum by a filter. (From J. L. Gehrich, D. W. Lübbers,

Exercise

Form groups of 2 or 3 students, and discuss:

a. What are the main differences between the pH, pCO_2 and pO_2 probe?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Case 4



- Blood gas status:
  - pH – 7.44
  - pO_2 – 11.9 kPa
  - pCO_2 – 4.6 kPa
  - Saturation (O_2%) – 97%

The blood was “chocolate-coloured” compared to control-blood

- What does this tell you?

Case 4



- Blood gases show a pH = 7.44, pO_2 = 11.9 kPa, pCO_2 = 4.6 kPa

X-ray of the chest and lungs were negative, ECG perfectly normal.

Her doctor decides to measure the saturation

Saturation

A relative measure of the amount of oxygen that is carried in blood by hemoglobin

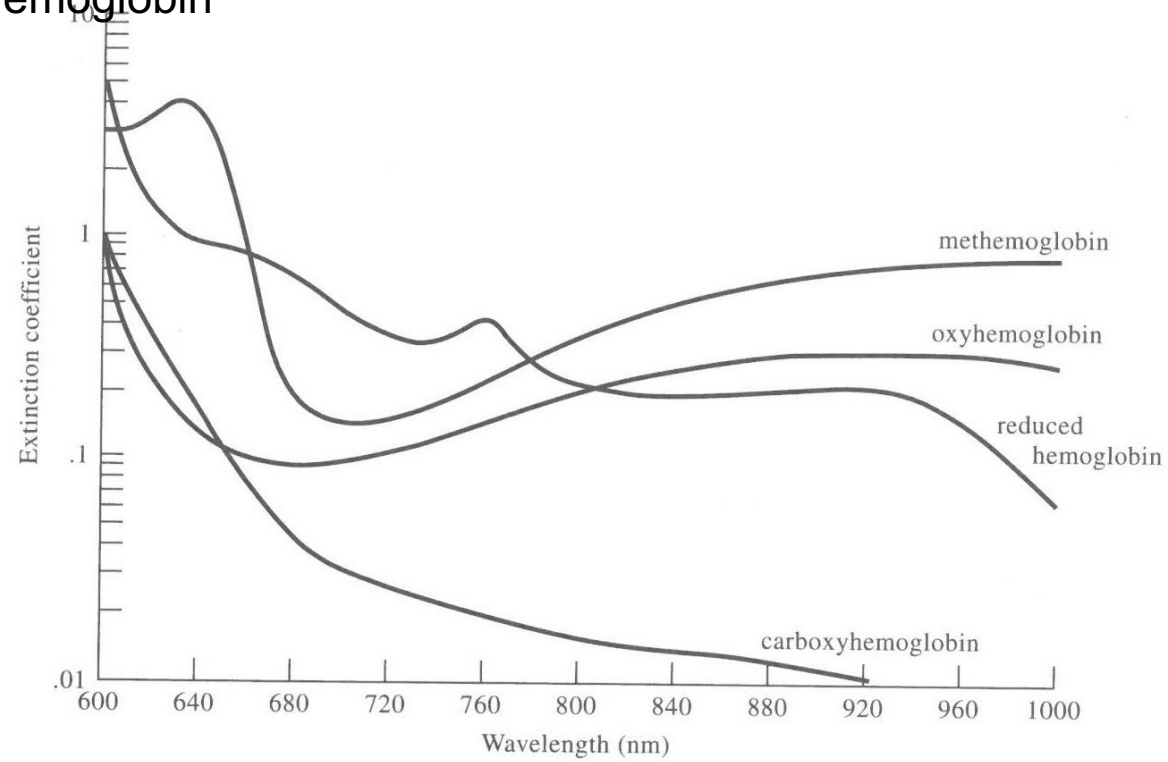


Figure 10.6 Absorptivities (extinction coefficients) in L/(mmol·cm) of the four most common hemoglobin species at the wavelengths of interest in pulse oximetry. (Courtesy of Susan Manson, Biox/Ohmeda, Boulder, CO.)

Saturation

Optical oximetry

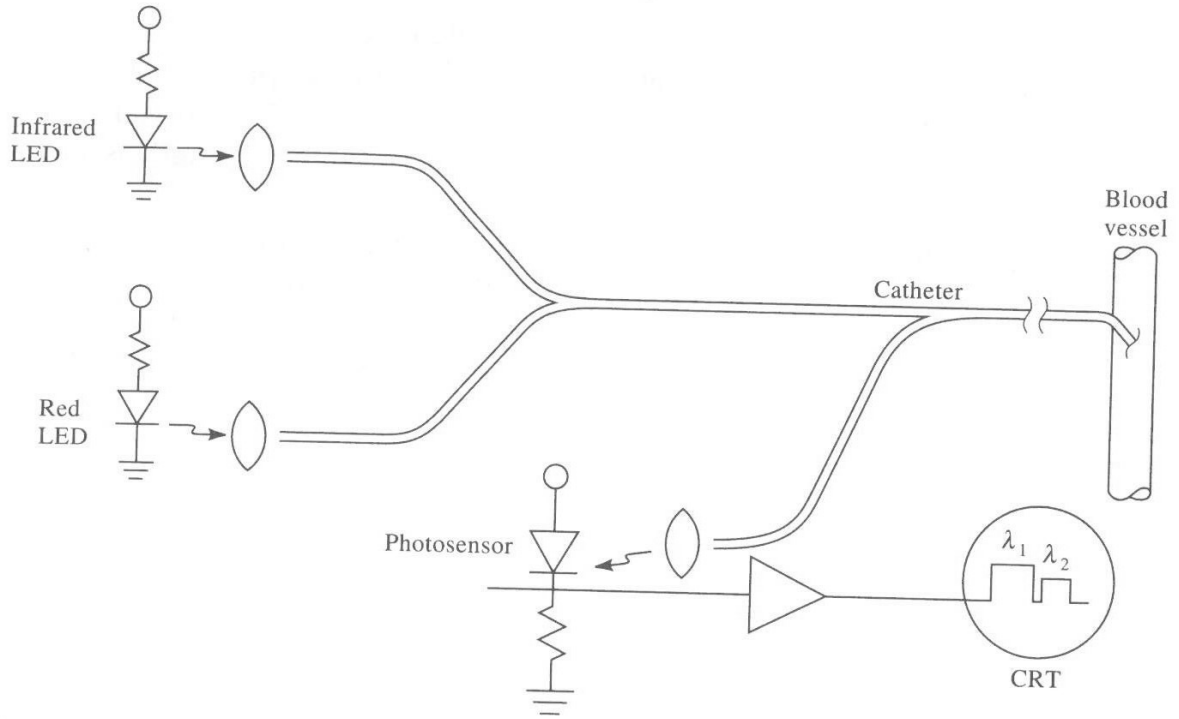


Figure 10.7 The oximeter catheter system measures oxygen saturation *in vivo*, using red and infrared light emitting diodes (LEDs) and a photosensor. The red and infrared LEDs are alternately pulsed in order to use a single photosensor.

Saturation

Fiberoptic oximetry

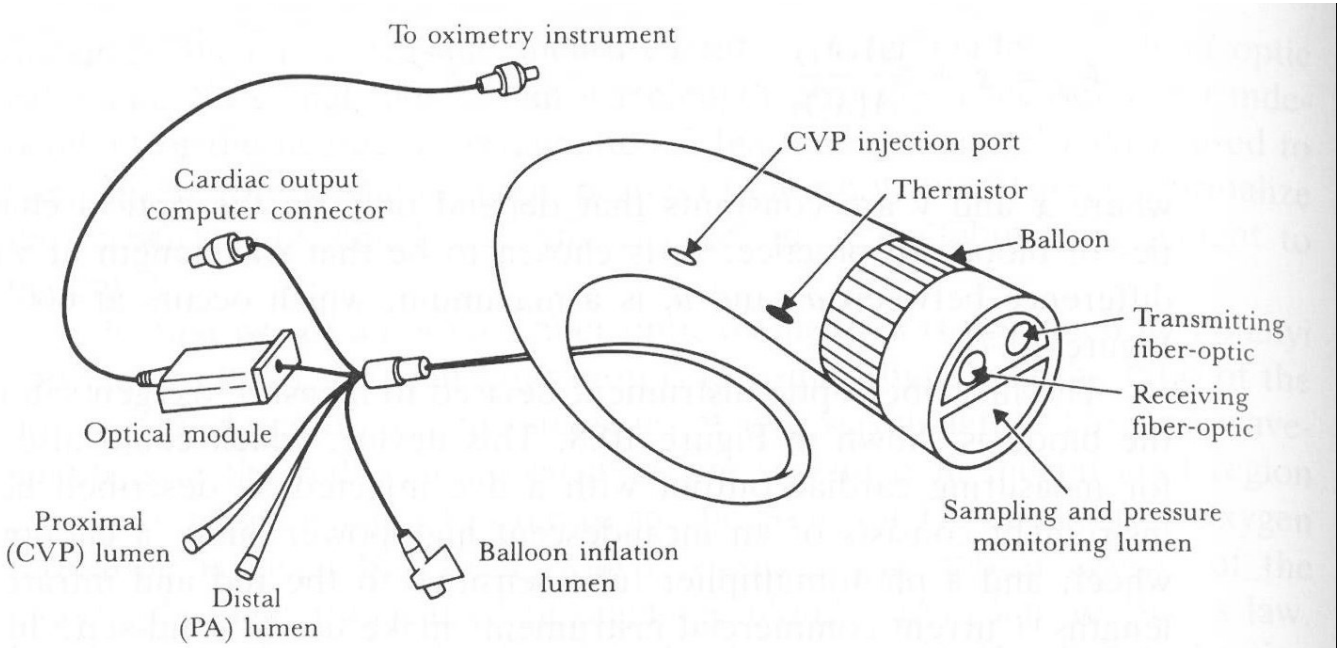


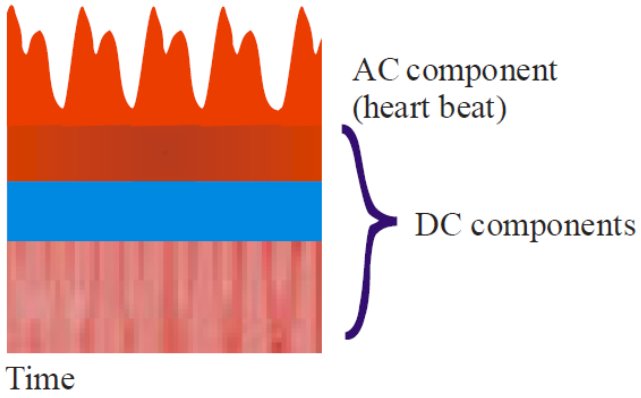
Figure 10.9 The catheter used with the Oximetrix Opticath Oximetry System transmits light to the blood through a transmitting optical fiber and returns the reflected light through a receiving optical fiber. The catheter is optically connected to the oximetry processor through the optical module. (From Oximetrix Incorporated. Used by permission.)

Pulse oximetry

Pulse oximetry definition: “The determination of arterial oxygen saturation by analysis of bi-spectral pulsatile waveforms” (Keith Simpson)

This means that we must make one assumption:
Arterial circulation is pulsatile, venous circulation is not





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Analyzing the AC component with two wavelengths.
DC component is used to normalize AC signals
Absorbance or reflection
2.5% accuracy within 50-100%
Saturation < 76% is life threatening

Pulse oximetry

PULSE oximetry, Lambert-Beer Law

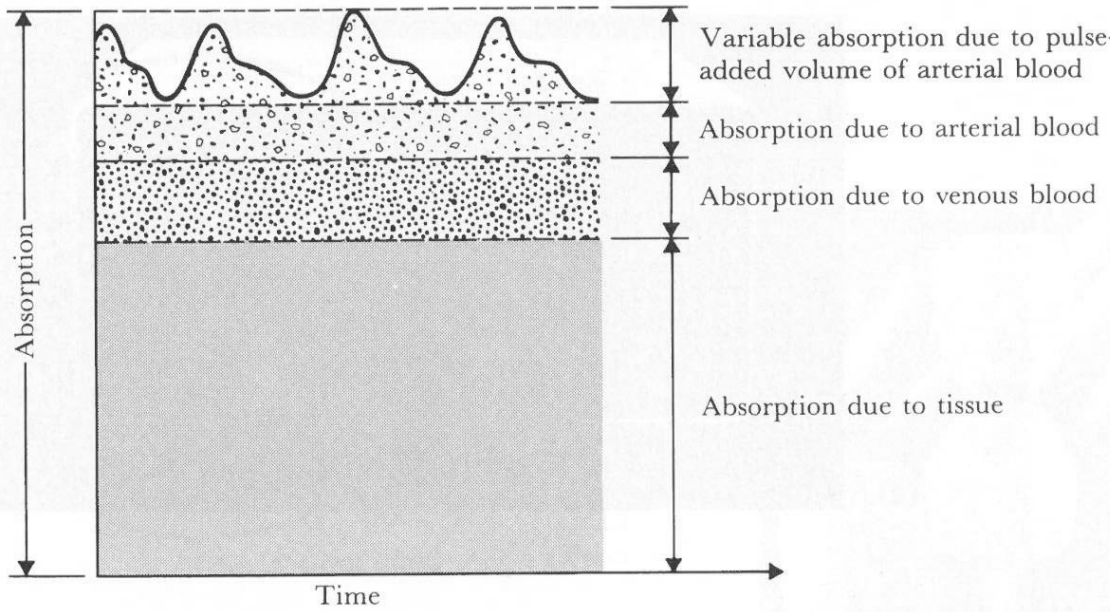


Figure 10.28 The pulse oximeter analyzes the light absorption at two wavelengths of only the pulse-added volume of oxygenated arterial blood. [From Y. M. Mendelson, "Blood gas measurement, transcutaneous," in J. G. Webster (ed.), *Encyclopedia of Medical Devices and Instrumentation*. New York: Wiley, 1988, pp. 448–459. Used by permission.]

Pulse oximetry

We measure 97% saturation for our patient, is everything ok then?

Remember: The Pulse-ox measures the % saturation of *haemoglobin only*

Case 4



- The regular pulse-oximeter shows a saturation of 97%, which is quite normal. To exclude any blood-flow problems due to the apparently more cyanotic left leg, the doctor decides to make a couple of simple flow measurements. By means of a thermistor already located in the blood stream at the tip of a shwan-ganz catheter monitoring the global blood flow, and the local blood flow in the left leg by means of a plethysmograph.

Depend on convective cooling of a heated sensor (over blood temperature) => local velocity

W (power)/delta T = a + b log u

High sensitivity and reasonable resistance values
a. Is direction insensitive

Termistor flowmeasurement

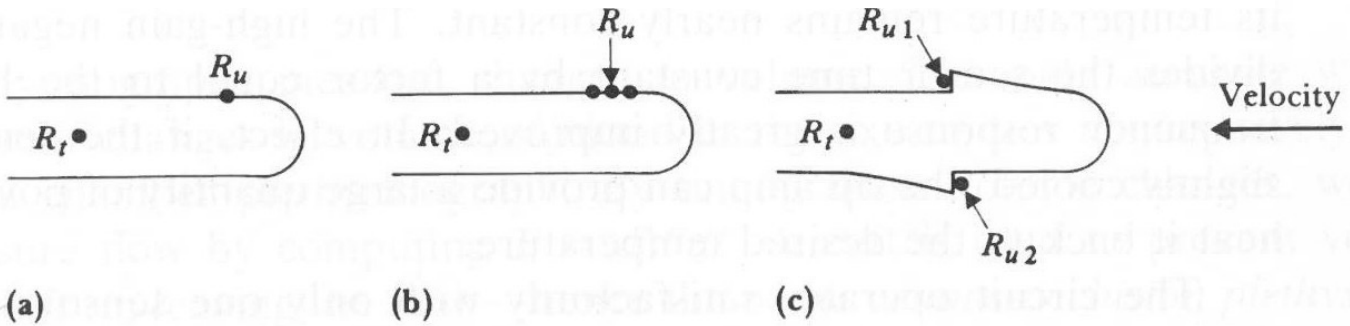


Figure 8.17 Thermal velocity probes (a) Velocity-sensitive thermistor R_u is exposed to the velocity stream. Temperature-compensating thermistor R_t is placed within the probe. (b) Thermistors placed down- and upstream from R_u are heated or not heated by R_u, thus indicating velocity direction. (c) Thermistors exposed to and shielded from flow can also indicate velocity direction.

Termistorbridge velocity meter

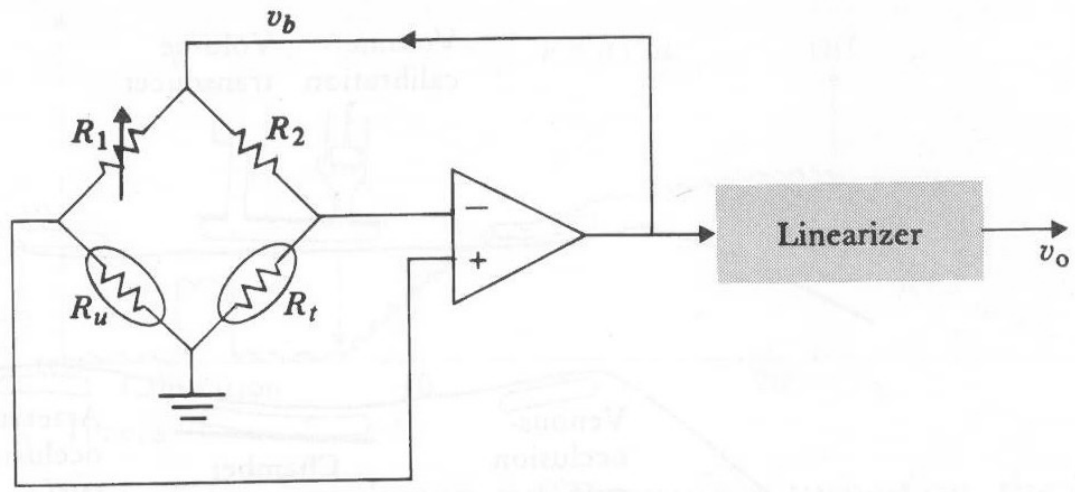
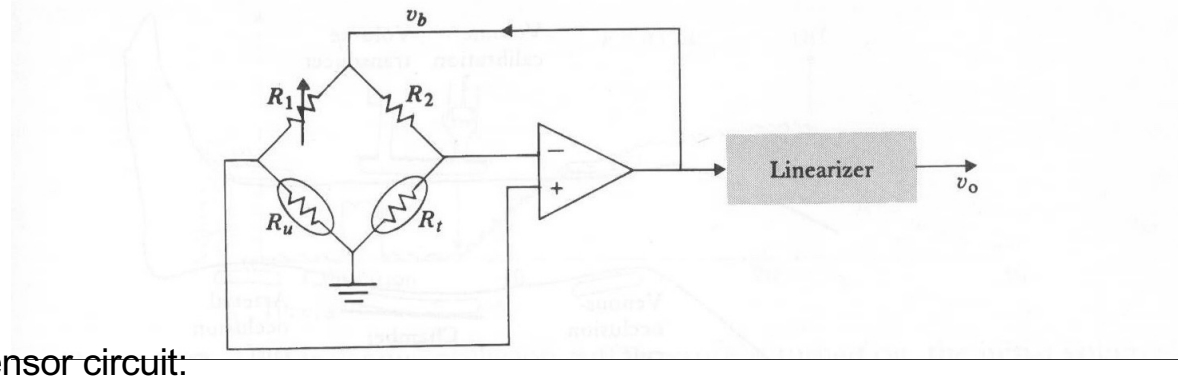


Figure 8.18 Thermal velocity meter circuit A velocity increase cools R_u, the velocity-measuring thermistor. This increases voltage to the noninverting op-amp input, which increases bridge voltage v_b and heats R_u. R_t provides temperature compensation.

Termistorbridge velocity meter



Two problems of constant current sensor circuit:

1. Time constant of the sensor embedded in the probe is a few tenths of a second, too long for the desired frequency respons of 0 to 25 Hz
2. To achieve reasonable sensitivity at high velocities -> high sensor current -> lack of cooling when flow stops -> increased temp (5 deg above body temp) ->fibrin coats the sensor

Constant temperature sensor overcomes problems:

Ru is heated. Velocity increases -> Ru cools and resistance increases -> more positive voltage on the pos terminal -> increased vb -> increased bridge power -> increased Ru -> cooling is counteracted

High-gain negative feedback -> bridge is always in balance -> constant temp at Ru

High gain negative feedback divides sensor time constant by a factor equal to the loop gain = improved frequency response

Varying blood temperature -> Rt (temperature compensating thermistor)

Plethysmography

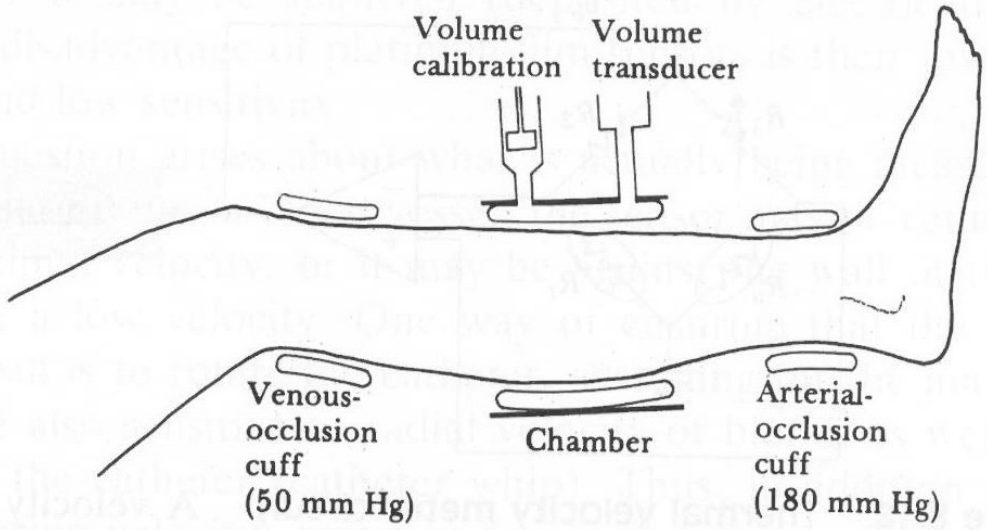


Figure 8.19 In chamber plethysmography, the venous-occlusion cuff is inflated to 50 mm Hg (6.7 kPa), stopping venous return. Arterial flow causes an increase in volume of the leg segment, which the chamber measures. The text explains the purpose of the arterial-occlusion cuff.

Plethysmography curve

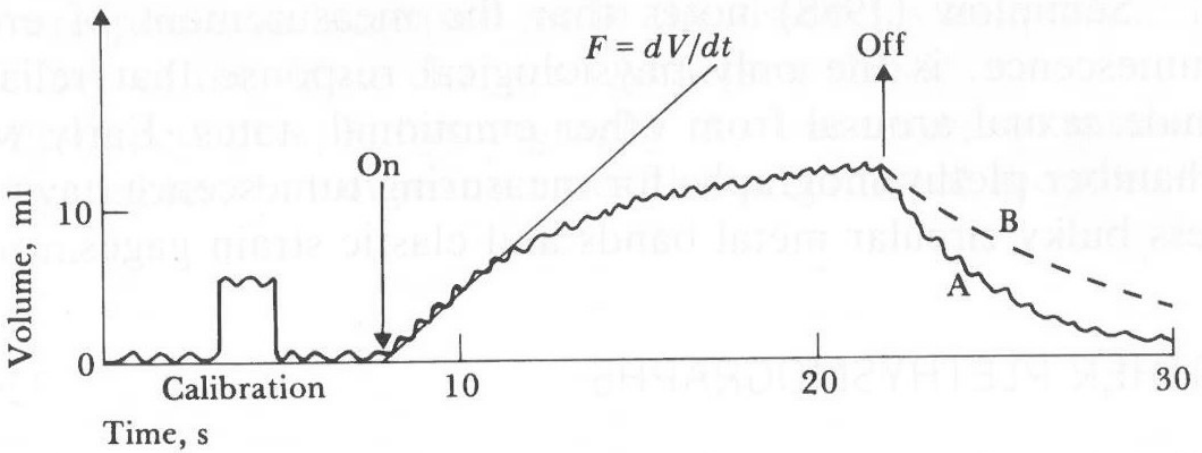
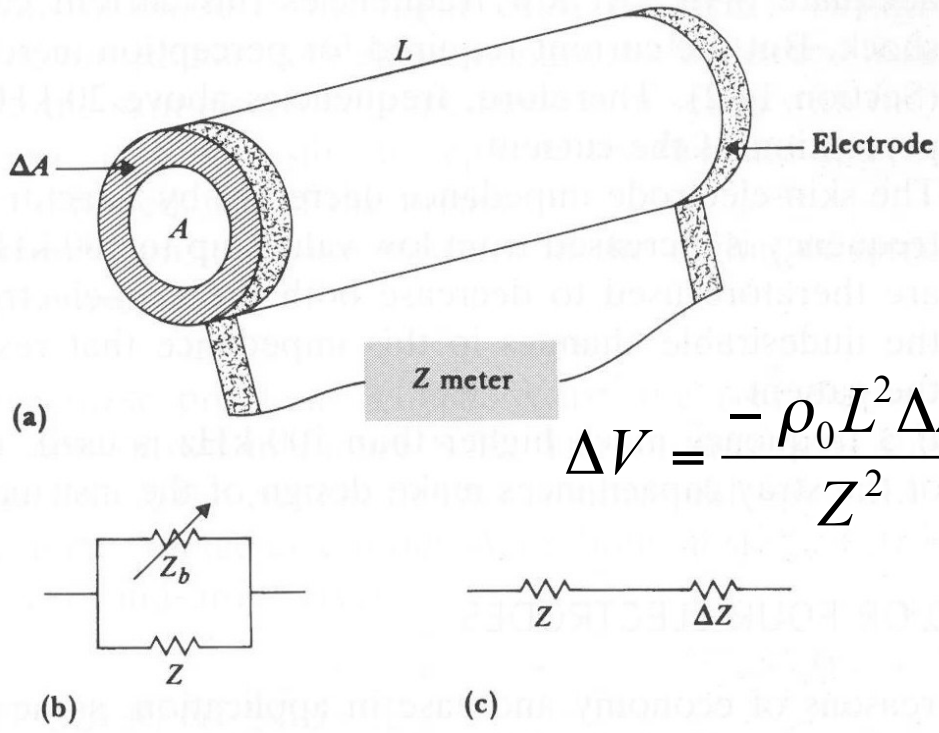


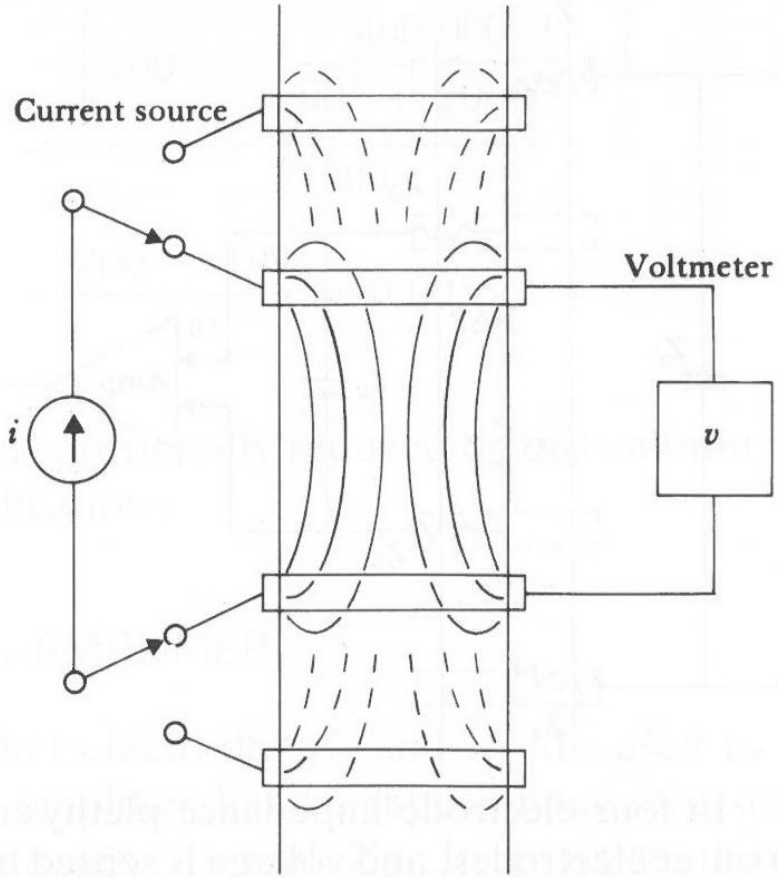
Figure 8.20 After venous-occlusion cuff pressure is turned on, the initial volume-versus-time slope is caused by arterial inflow. After the cuff is released, segment volume rapidly returns to normal (A). If a venous thrombosis blocks the vein, return to normal is slower (B).

Impedance-plethysmography



$$\Delta V = \frac{-\rho_0 L^2 \Delta Z}{Z^2} = \rho_0 L^2 \Delta G$$

Figure 8.21 (a) A model for impedance plethysmography. A cylindrical limb has length L and cross-sectional area A. With each pressure pulse, A increases by the shaded area ΔA. (b) This causes impedance of the blood, Z_b, to be added in parallel to Z. (c) Usually ΔZ is measured instead of Z_b.



2- or 4-electrode

Figure 8.22 In two-electrode impedance plethysmography, switches are in the position shown, resulting in a high current density (solid lines) under voltage-sensing electrodes. In four-electrode impedance plethysmography, switches are thrown to the other position, resulting in a more uniform current density (dashed lines) under voltage-sensing electrodes.

4-electrode plethysmography

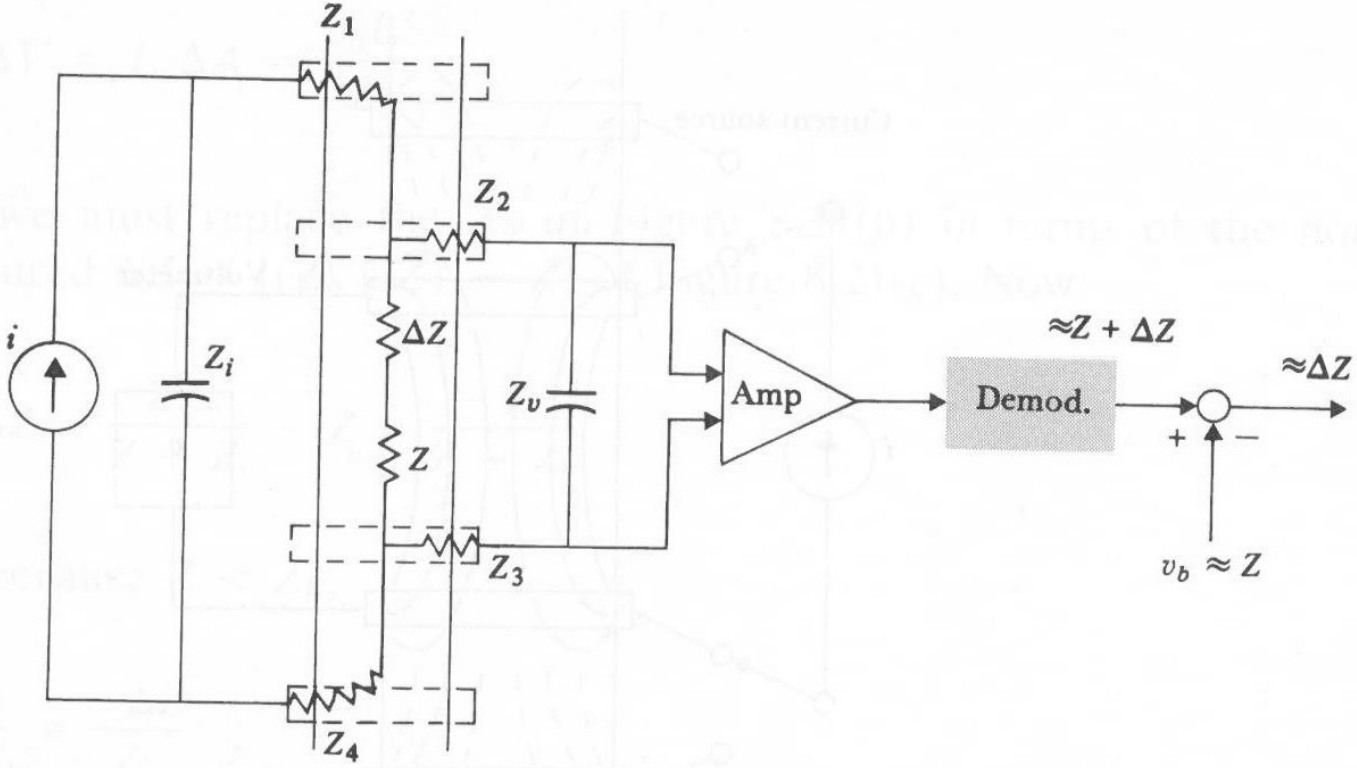


Figure 8.23 In four-electrode impedance plethysmography, current is injected through two outer electrodes, and voltage is sensed between two inner electrodes. Amplification and demodulation yield $Z + \Delta Z$. Normally, a balancing voltage v_b is applied to produce the desired ΔZ.

Photoplethysmography

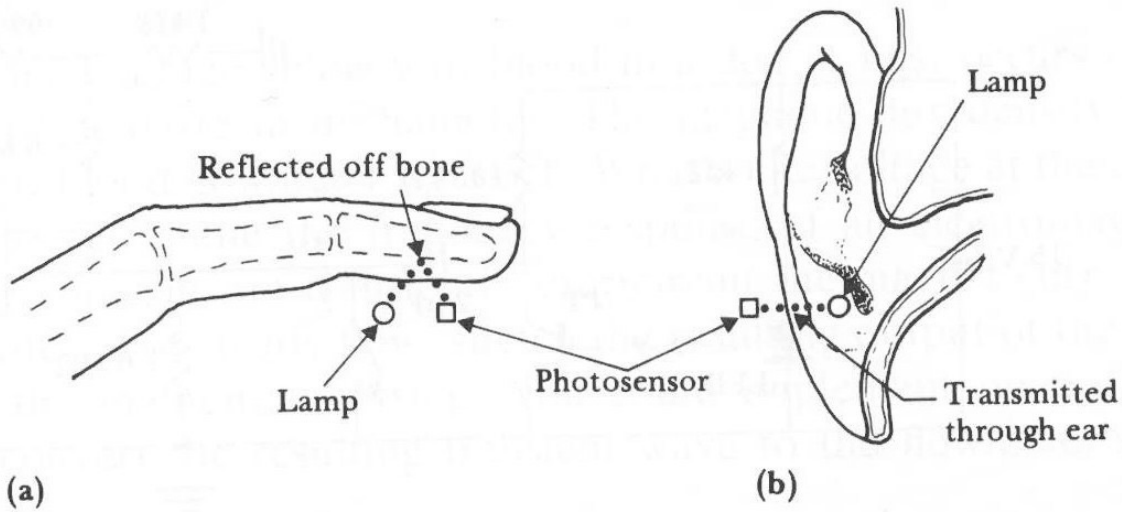


Figure 8.25 (a) Light transmitted into the finger pad is reflected off bone and detected by a photosensor. (b) Light transmitted through the aural pinna is detected by a photosensor.

Photoplethysmography

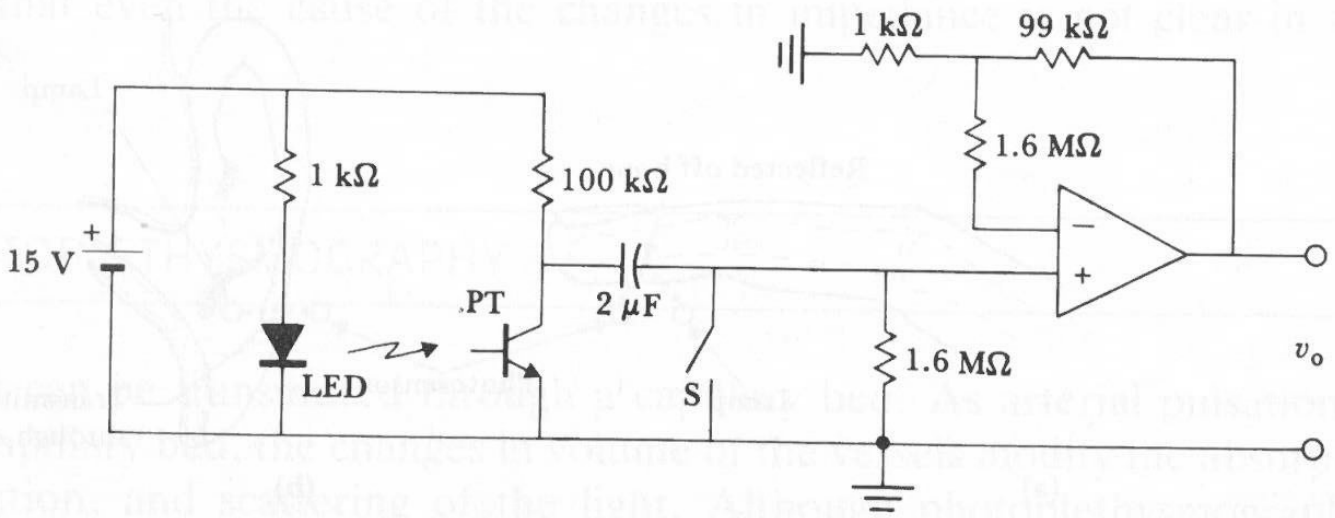


Figure 8.26 In this photoplethysmograph, the output of a light-emitting diode is altered by tissue absorption to modulate the phototransistor. The dc level is blocked by the capacitor, and switch S restores the trace. A noninverting amplifier can drive low impedance loads, and it provides a gain of 100.

Case 4





- MetHb is a form of hemoglobin that contains Fe^{3+} instead of Fe^{2+}. Fe^{3+} has a reduced affinity to oxygen, but the remaining Fe^{2+} in the same molecule will increase the affinity to oxygen. In consequence, the hemoglobin will experience reduced ability to release oxygen to tissues, a left shift in the oxygen-hemoglobin dissociation curve. This can lead to tissue hypoxia. MetHb can be congenital or a result of certain drugs like Dapson.

- What is wrong?

Case 4



- Answer: The MetHb-level was 48%, it should be below 1% so it is clearly a methemoglobinemia. There are mainly two possible causes of methemoglobinemia, and if it was congenital this would have been exposed years ago. The remaining explanation is a drug intoxication, and after a confrontation with her doctor she admits a suicide attempt taking 100 tablets of Dapson 50 mg and 180 tablets of Retrovir. She was treated with methylene blue, which converts MetHb to Hb, and was discharged on day 7. No aftereffects except a light hemolysis, psychiatric treatment was prescribed.