Chapter 7. Blood Pressure and Sound

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ÇANKAYA ÜNİVERSİTESİ
MEKATRONİK MÜHENDİSLİĞİ BÖLÜMÜ

- Blood-pressure values in the various chambers of the heart and in the peripheral vascular system help the physician determine the functional integrity of the cardiovascular system.
- Fluctuations in pressure recorded over the frequency range of hearing are called sounds. The sources of heart sounds are the vibrations set up by the accelerations and decelerations of blood.
- The function of the blood circulation is to transport oxygen and other nutrients to the tissues of the body and to carry metabolic waste products away from the cells.

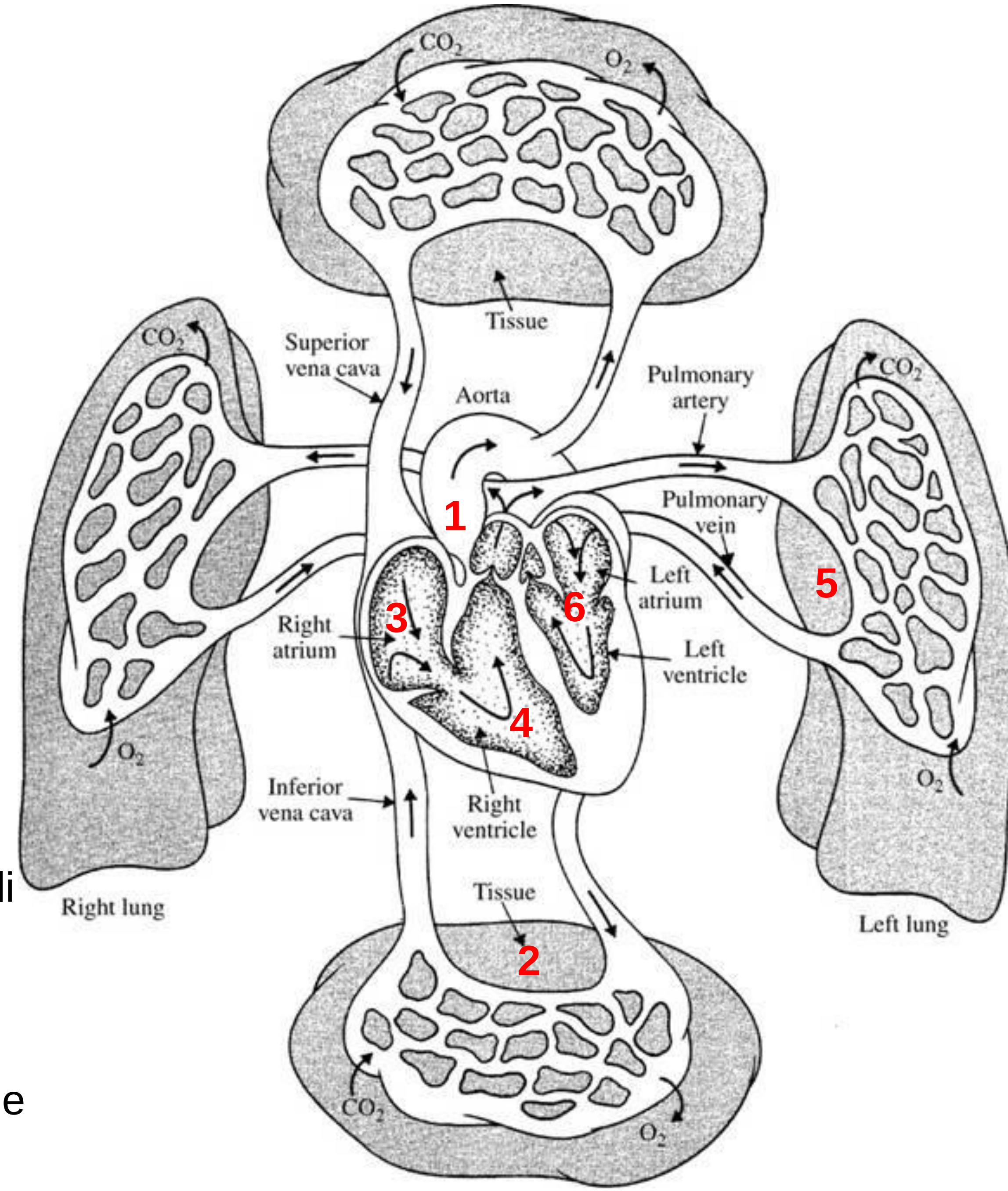
Blood pressure

- Blood is pumped around the body by the heart.
- It makes its way around the body through a network of tubes known as the vascular system.
- Together with the heart they form the cardiovascular system.

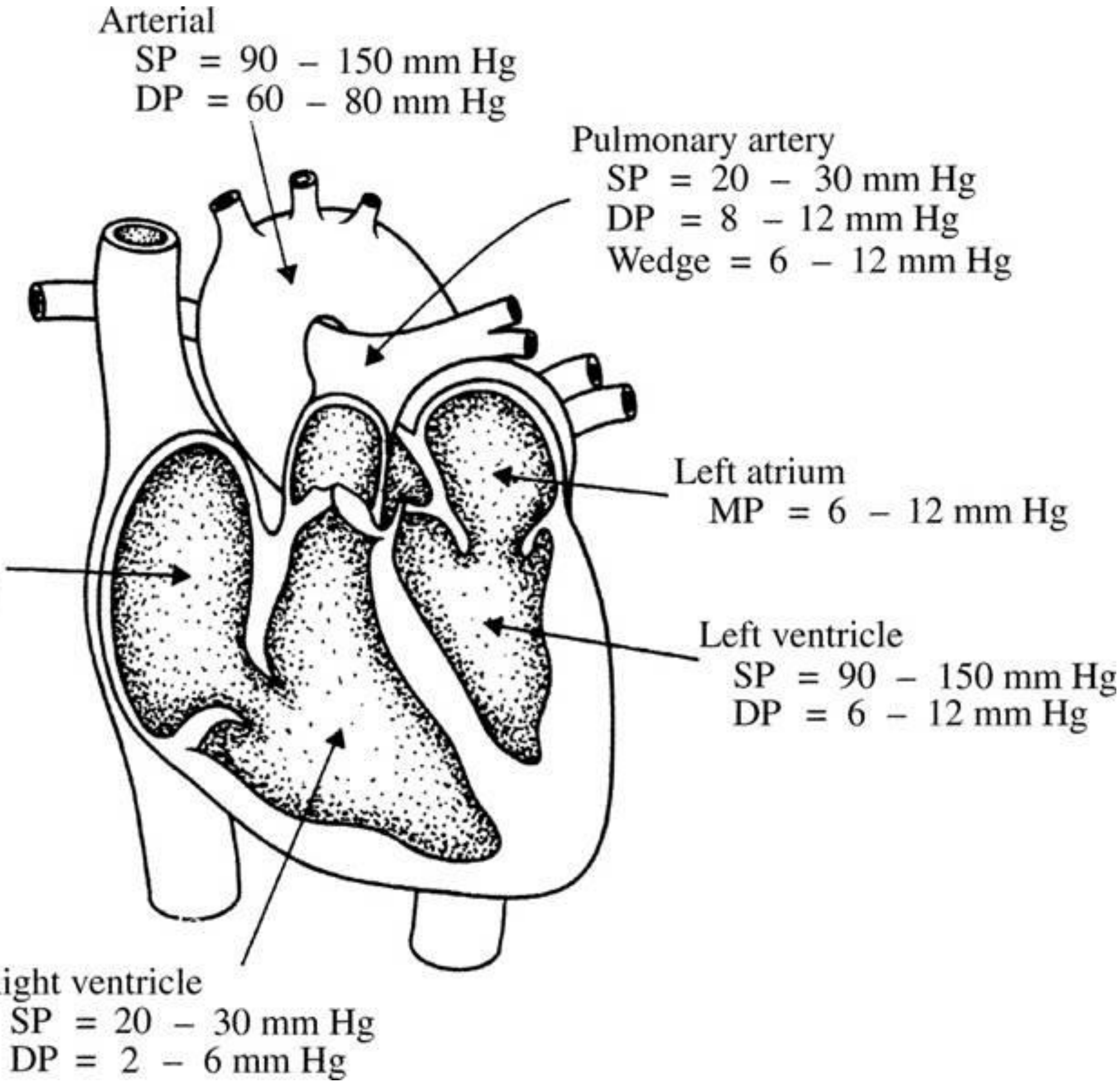
The vascular system

- Three sub-systems:
- Arteries: high-pressure arterial tubes which carry the blood away from the heart
- Capillary network: fine, thin-walled tubes which allow transfer of nutrients & oxygen into cells and the removal of waste products from the cells
- Veins: low-pressure tubes which return the blood to the heart

1. When the **left ventricle** contracts in response to the electric **stimulation** of the myocardium the **left ventricle** ejects blood through the **aortic valve** into the aorta.
2. The exchange of the nutrient material takes place at the **capillary level**.
3. The blood then returns to **right atrium**, then to the **right ventricle**.
4. The blood is pumped from the **right ventricle** into the **pulmonary artery** through the pulmonary valve.
5. At the **pulmonary capillaries**, O2 diffuses from the lung alveoli to the blood and CO2 diffuses from the blood to the alveoli.
6. The blood flows from the **left atrium**, the filling chamber of the left heart, through the mitral valve into the **left ventricle**.

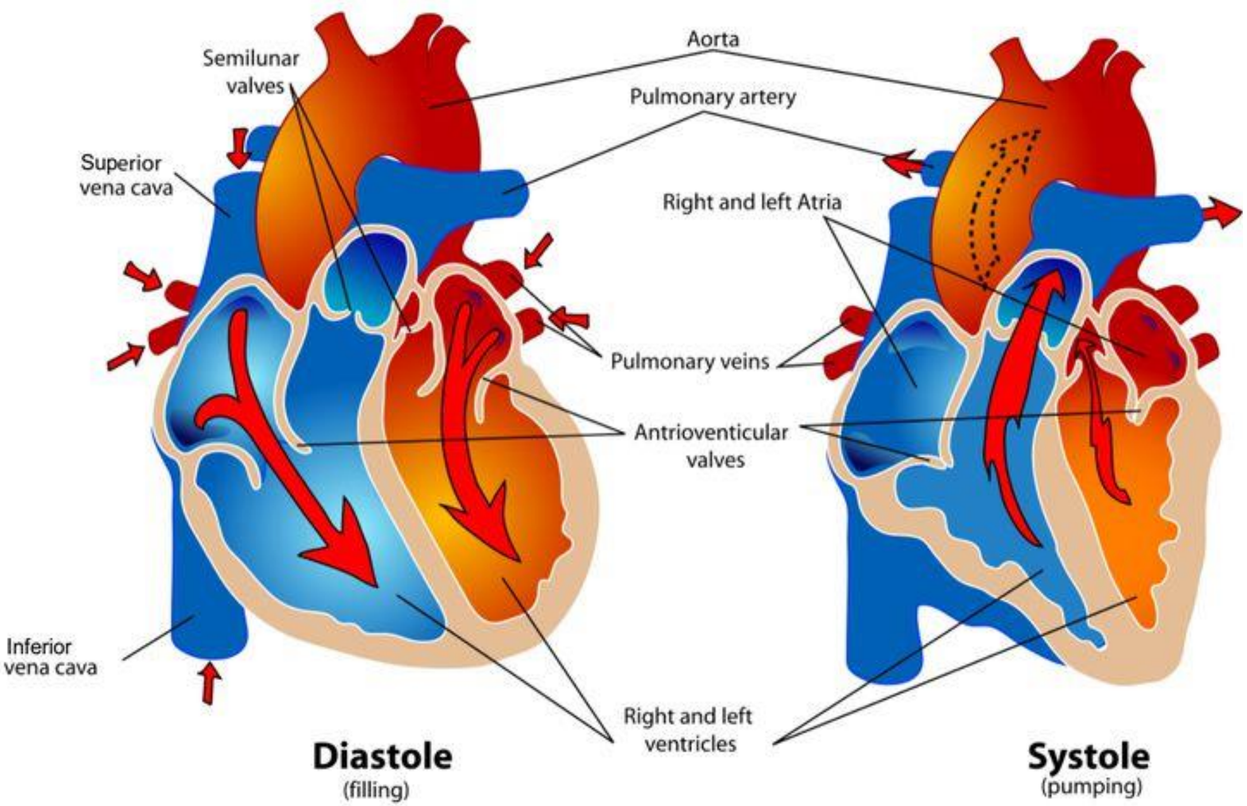


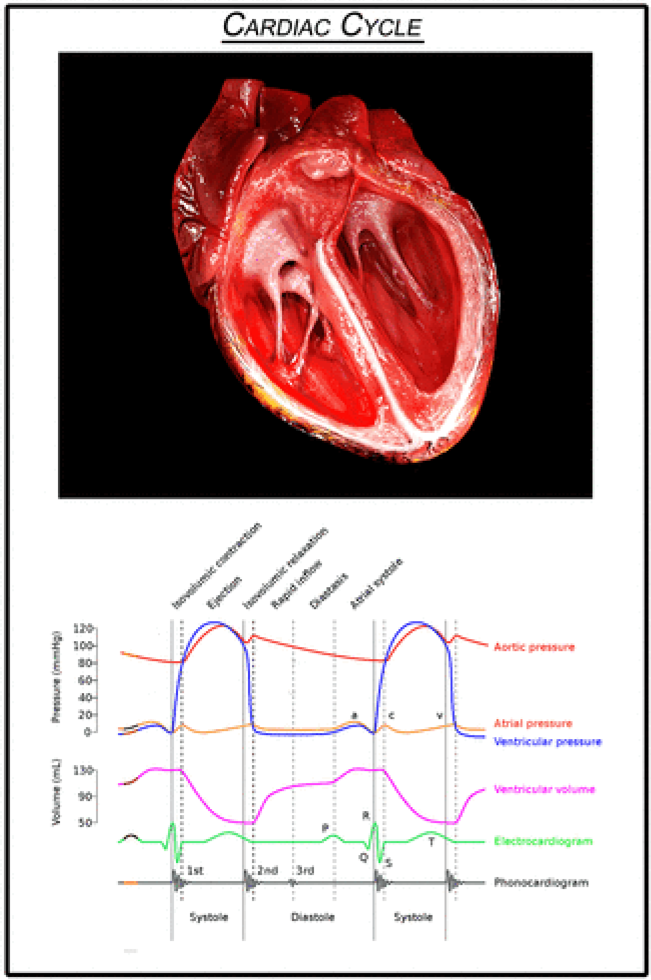
Typical values of circulatory pressures SP is the systolic pressure, DP the diastolic pressure, and MP the mean pressure.



Electrical impulse causes mechanical contraction of ventricular muscle generates ventricular pressures that force blood through the pulmonary and aortic valves into the pulmonary circulation and the systemic circulation, causing pressures in each. Section 7.9 describes the correlation of the four heart sounds with the

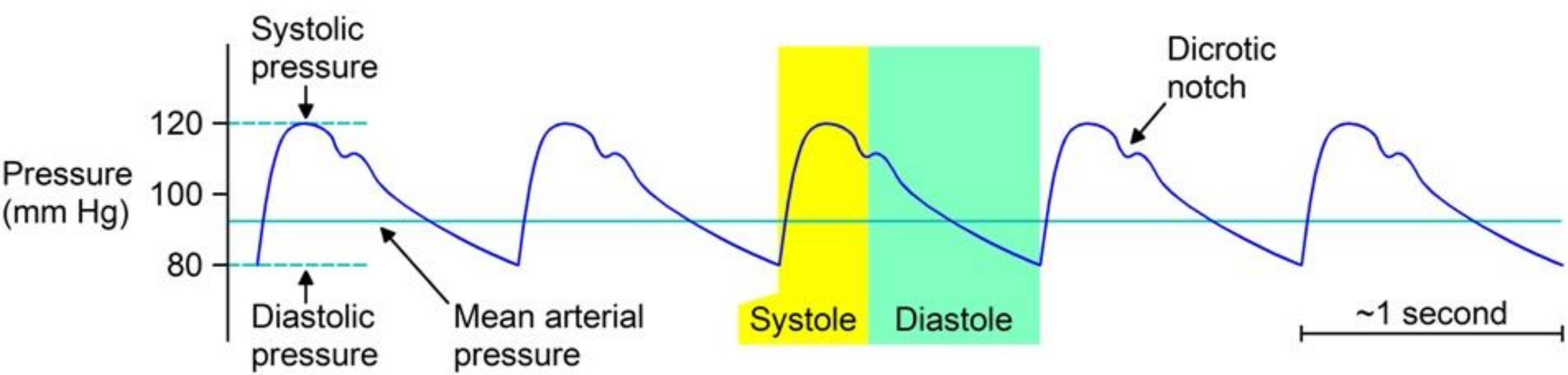
- A single cycle of cardiac activity can be divided into two basic phases - **diastole** and **systole**.
- During the contraction phase (systole), blood is ejected from both the left and right ventricles and pumped into the systemic circulation and pulmonary circulation, respectively.
- During the relaxation phase of the heart (diastole), the ventricles are filled with blood in preparation for the next contraction phase.





Pressure measurements

- The cycles of ventricular contraction and relaxation lead to maximum (systolic) and minimum (diastolic) levels of blood pressure in the major arteries in which blood is initially pumped.
- Blood pressure is generally recorded using two measurements (in mmHg):
  - Systolic Pressure
  - Diastolic Pressure
- Blood pressure is usually reported as "Systolic over Diastolic“; e.g. 120/70 is a systolic pressure of 120 mmHg and a diastolic pressure of 70 mmHg.



- Systolic and diastolic arterial blood pressure values are important measurements and have tremendous diagnostic value as shown in table.
- **The mean arterial pressure (MAP)** that drives blood through the vasculature from the arteries to arterioles, capillaries, venules, veins, and back to the heart
- The mean arterial pressure is a time-weighted average of pressure values in large systemic arteries during the cardiac cycle.
- The ventricles spend approximately one-third (1/3) of their time in systole, and two-thirds (2/3) in diastole.

$$\mathbf{MAP = (2/3)\ DBP + (1/3)\ SBP}$$

- The mean arterial pressure is a function of
  - (1) the rate at which the heart pumps blood into the large arteries,
  - (2) the rate of blood flow out of the large arteries to enter smaller arteries and arterioles, and
  - (3) arterial wall compliance.
- **Pulse Pressure**, the difference between systolic and diastolic pressures

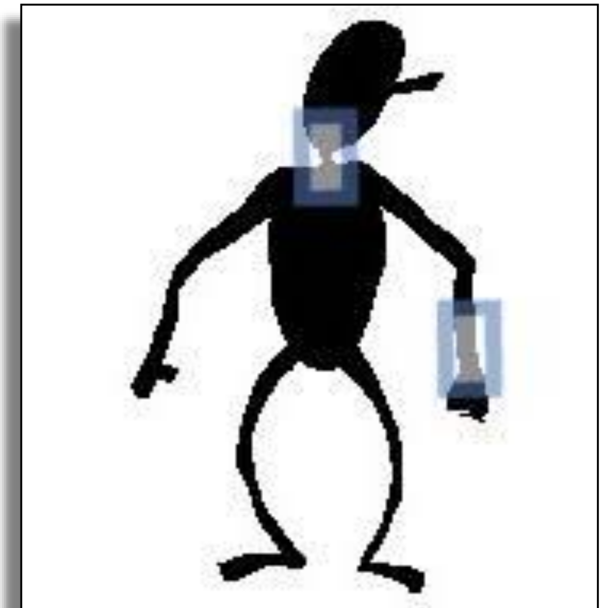
Table 1. Normal and abnormal arterial blood pressure values

Classification	Diastolic Pressure (mm Hg)	Systolic Pressure (mm Hg)
Hypotension	< 60	< 90
Normal	60 – 79	90 – 119
Prehypertension	80 – 89	120 – 139
Stage 1 Hypertension	90 – 99	140 – 159
Stage 2 Hypertension	≥ 100	≥ 160

General Facts

Direct measurement = Invasive measurement

A vessel is punctured and a catheter (a flexible tube) is guided in



The most common sites are brachial and radial arteries but also other sites can be used e.g. femoral artery

A division is made into **extravascular** and **intravascular** sensor systems

This method is precise but it is also a complex procedure involving many risks….

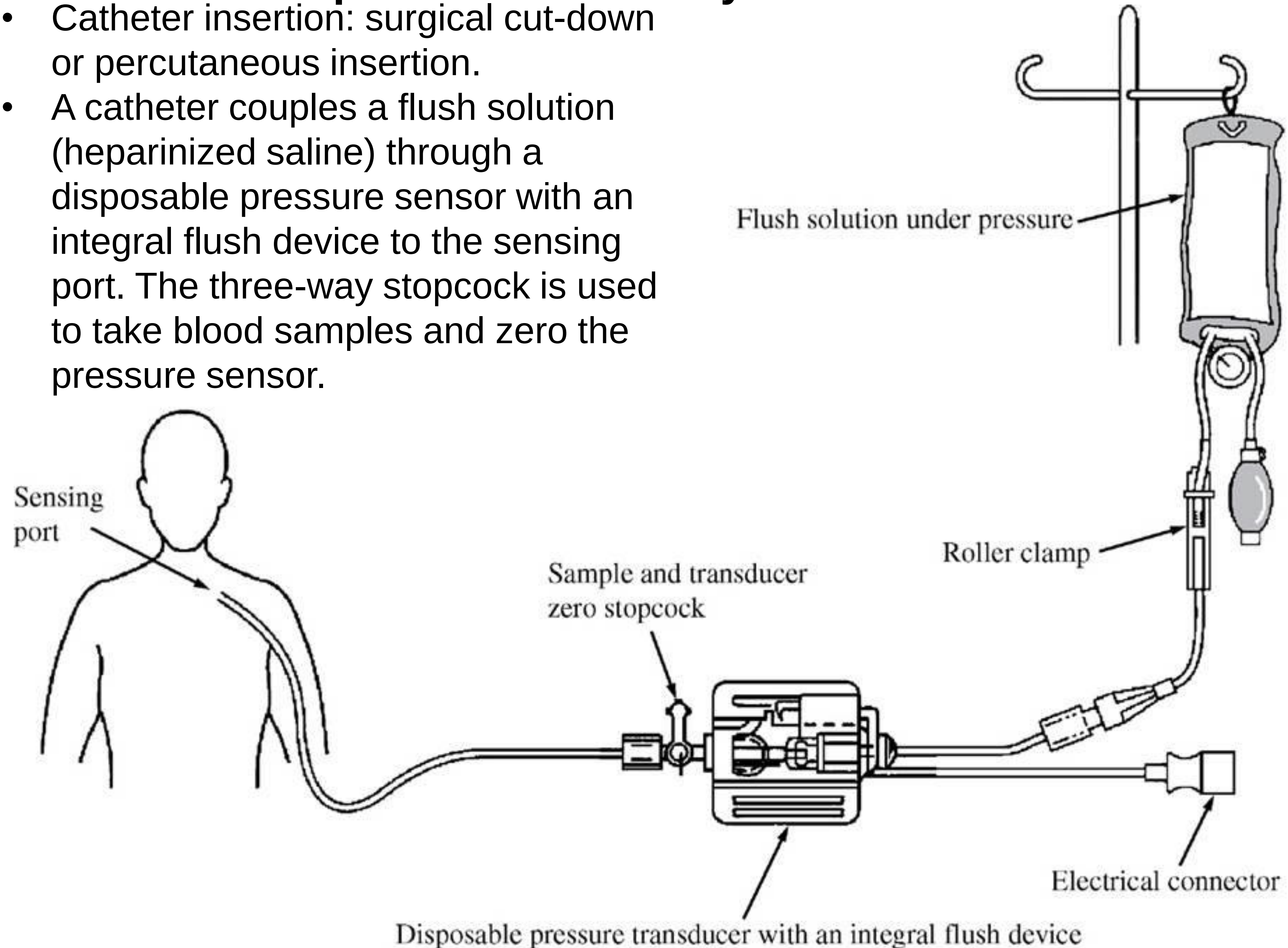
Used only when essential to determine the blood pressure continuously and accurately in dynamic circumstances

Direct Measurements

- Blood-pressure sensor systems can be divided into two general categories according to the location of the sensor element.
- Extravascular pressure sensor
  - The most common clinical method for directly measuring pressure is to couple the vascular pressure to an external sensor element via a liquid-filled catheter.
- Intravascular pressure sensor
  - The liquid coupling is eliminated by incorporating the sensor into the tip of a catheter that is placed in the vascular system.

Extravascular pressure-sensor system

- Catheter insertion: surgical cut-down or percutaneous insertion.
- A catheter couples a flush solution (heparinized saline) through a disposable pressure sensor with an integral flush device to the sensing port. The three-way stopcock is used to take blood samples and zero the pressure sensor.



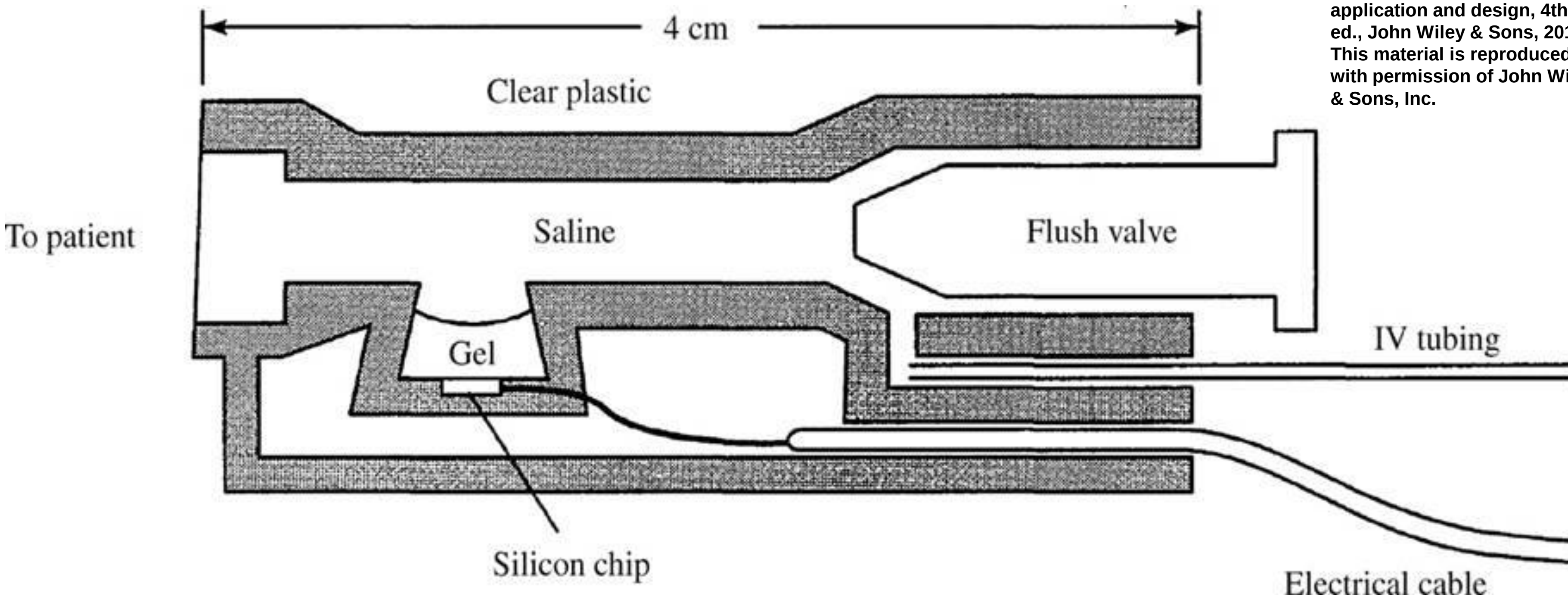
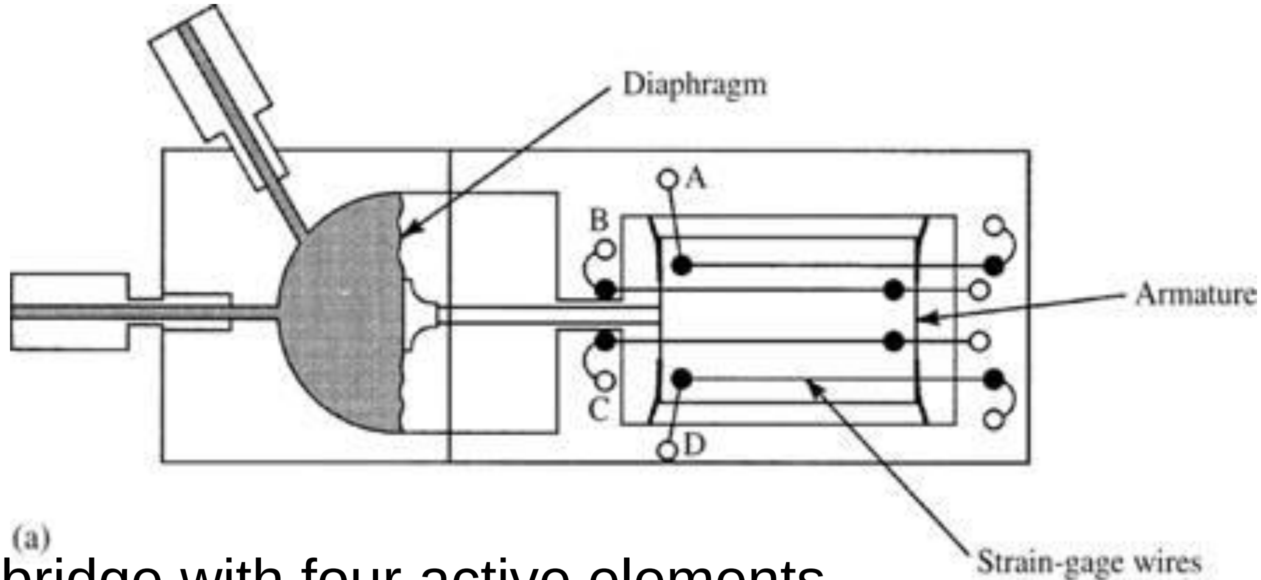


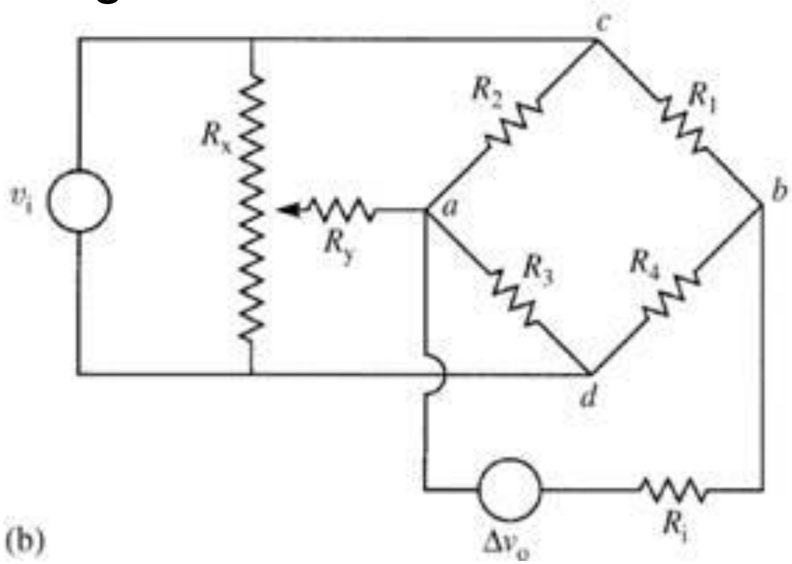
Figure 2.5 Isolation in a disposable blood-pressure sensor. Disposable blood pressure sensors are made of clear plastic so air bubbles are easily seen. Saline flows from an intravenous (IV) bag through the clear IV tubing and the sensor to the patient. This flushes blood out of the tip of the indwelling catheter to prevent clotting. A lever can open or close the flush valve. The silicon chip has a silicon diaphragm with a four-resistor Wheatstone bridge diffused into it. Its electrical connections are protected from the saline by a compliant silicone elastomer gel, which also provides electrical isolation. This prevents electric shock from the sensor to the patient and prevents destructive currents during defibrillation from the patient to the silicon chip.

(a) Unbonded strain-gage pressure sensor. The diaphragm is directly coupled by an armature to an unbonded strain-gage system. With increasing pressure, the strain on gage pair B and C is increased, while that on gage pair A and D is decreased,



(a)

(b) Wheatstone bridge with four active elements.

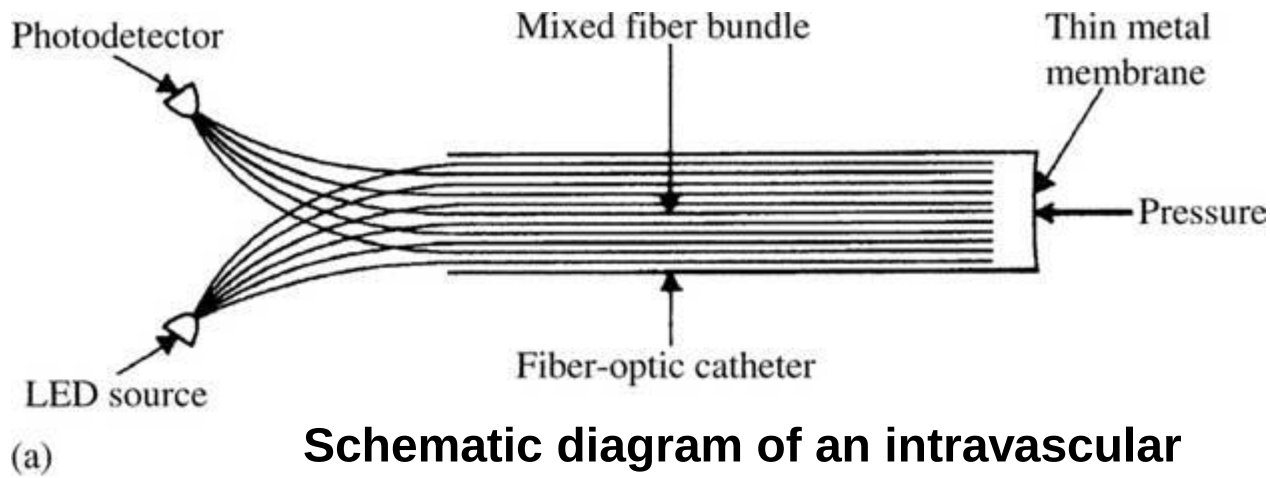


(b)

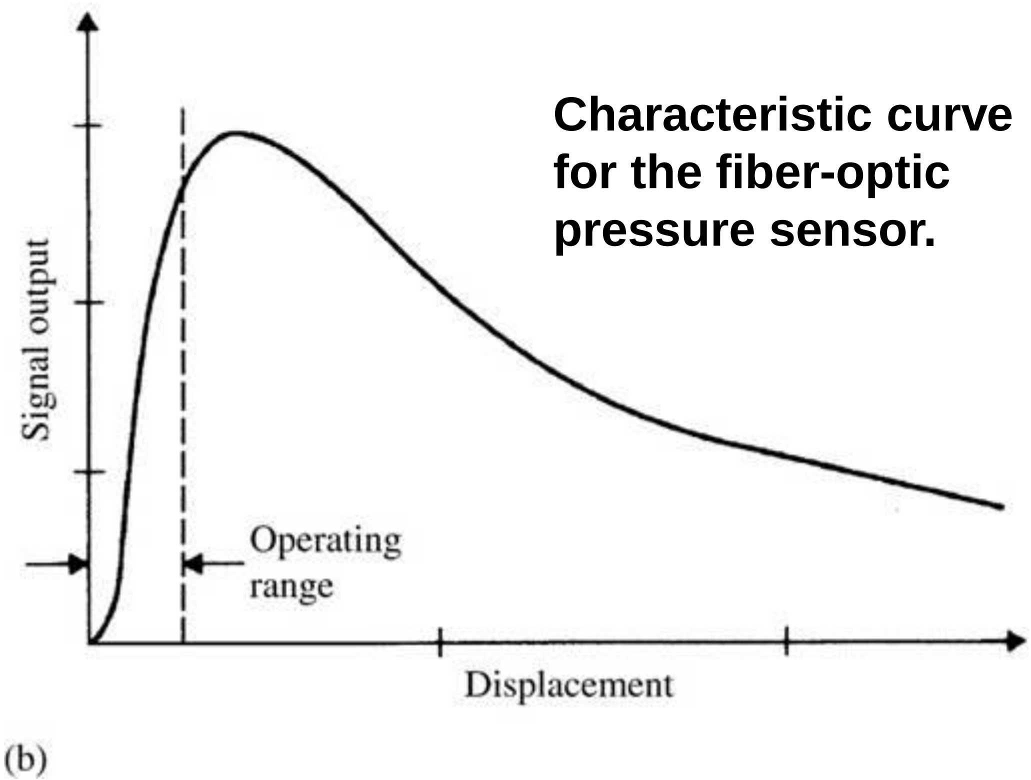
INTRAVASCULAR SENSORS

- Catheter-tip sensors have the advantage that the hydraulic connection via the catheter, between the source of pressure and the sensor element, is eliminated.
- Detection of pressures at the tip of the catheter without the use of a liquid-coupling system can thus enable the physician to obtain a high frequency response and eliminate the time delay encountered when the pressure pulse is transmitted in a catheter–sensor system.
- The frequency response of the catheter–sensor system is limited by the hydraulic properties of the system.
- For the detection of pressure in the catheter tip, straingage systems is bonded onto a flexible diaphragm at the catheter tip (1.67 mm outer diameter size).

- The fiber-optic intravascular pressure sensor can be made in sizes comparable to strain gages, but at a lower cost.
- The fiber-optic device measures the displacement of the diaphragm optically by the varying reflection of light from the back of the deflecting diaphragm.
- Pressure causes deflection in a thin metal membrane that modulates the coupling between the source and detector fibers



Schematic diagram of an intravascular fiber-optic pressure sensor.



Characteristic curve for the fiber-optic pressure sensor.

Device is applied to the anterior fontanel. Pressure is applied with the sensor such that the curvature of the skin surface is flattened. When this applanation occurs, equal pressure exists on both sides of the membrane, which consists of soft tissue between the scalp surface and the dura. Monitoring of the probe pressure determines the dura pressure. Pressure bends the membrane, which moves a reflector. This varies the amount of light coupling between the source and detector fibers.

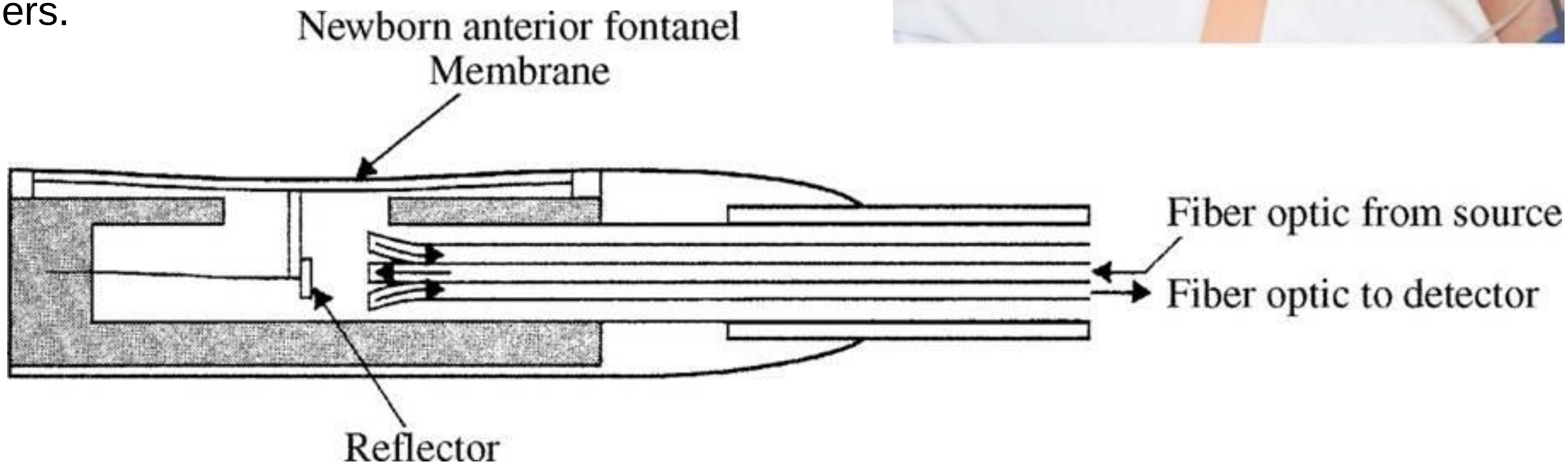


Figure 7.5 Fiber-optic pressure sensor for intracranial pressure measurements in the newborn. The sensor membrane is placed in contact with the anterior fontanel of the newborn.

Heart Sounds and Murmurs

- Auscultation of the heart gives the clinician valuable information about the functional integrity of the heart.
- Heart sounds are vibrations or sounds due to the acceleration or deceleration of blood
- Murmurs are vibrations or sounds due to blood turbulence.

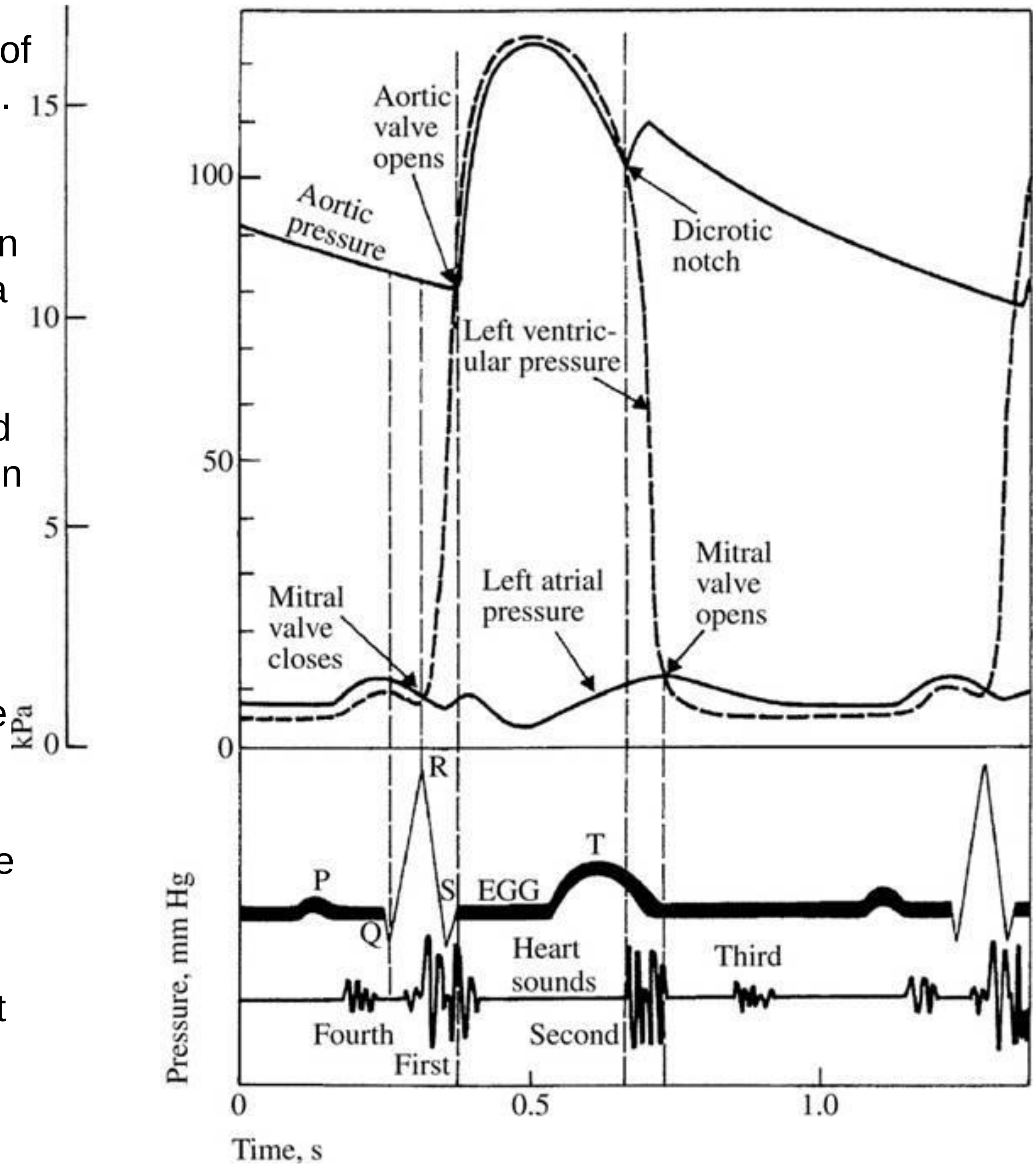
•**The first heart sound** is associated with the movement of blood during ventricular systole.

•**The second heart sound** is a low-frequency vibration associated with the deceleration and reversal of flow in the aorta and pulmonary artery and with the closure of the semilunar valves This second heart sound is coincident with the completion of the T wave of the ECG.

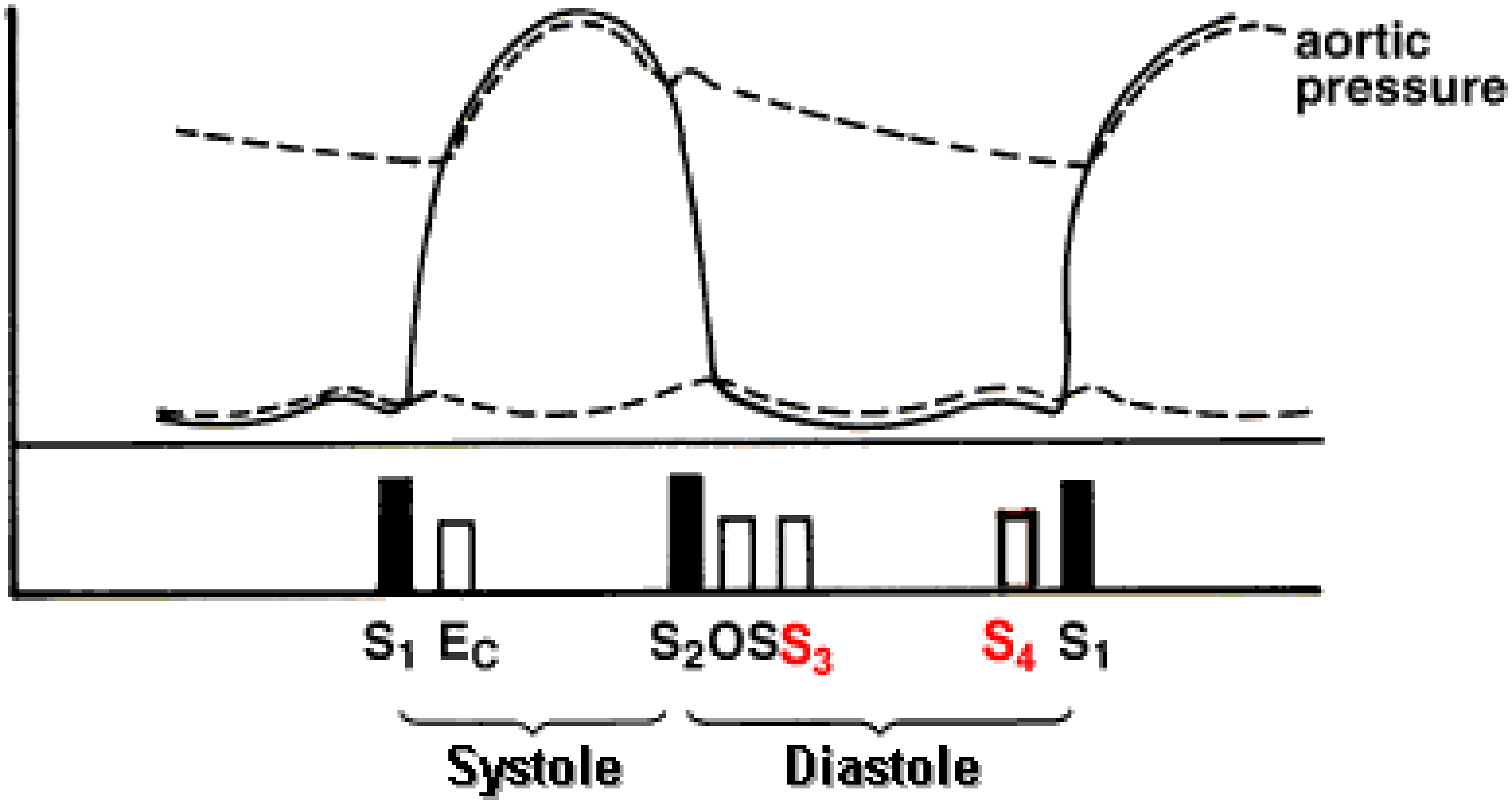
•**The third heart sound** is attributed to the sudden termination of the rapid-filling phase of the ventricles from the atria

•**The fourth or atrial heart sound** is not audible but can be recorded by the phonocardiogram

•Occurs when the atria contract and propel blood into the ventricles.



- S1, S2
- S3
- S4



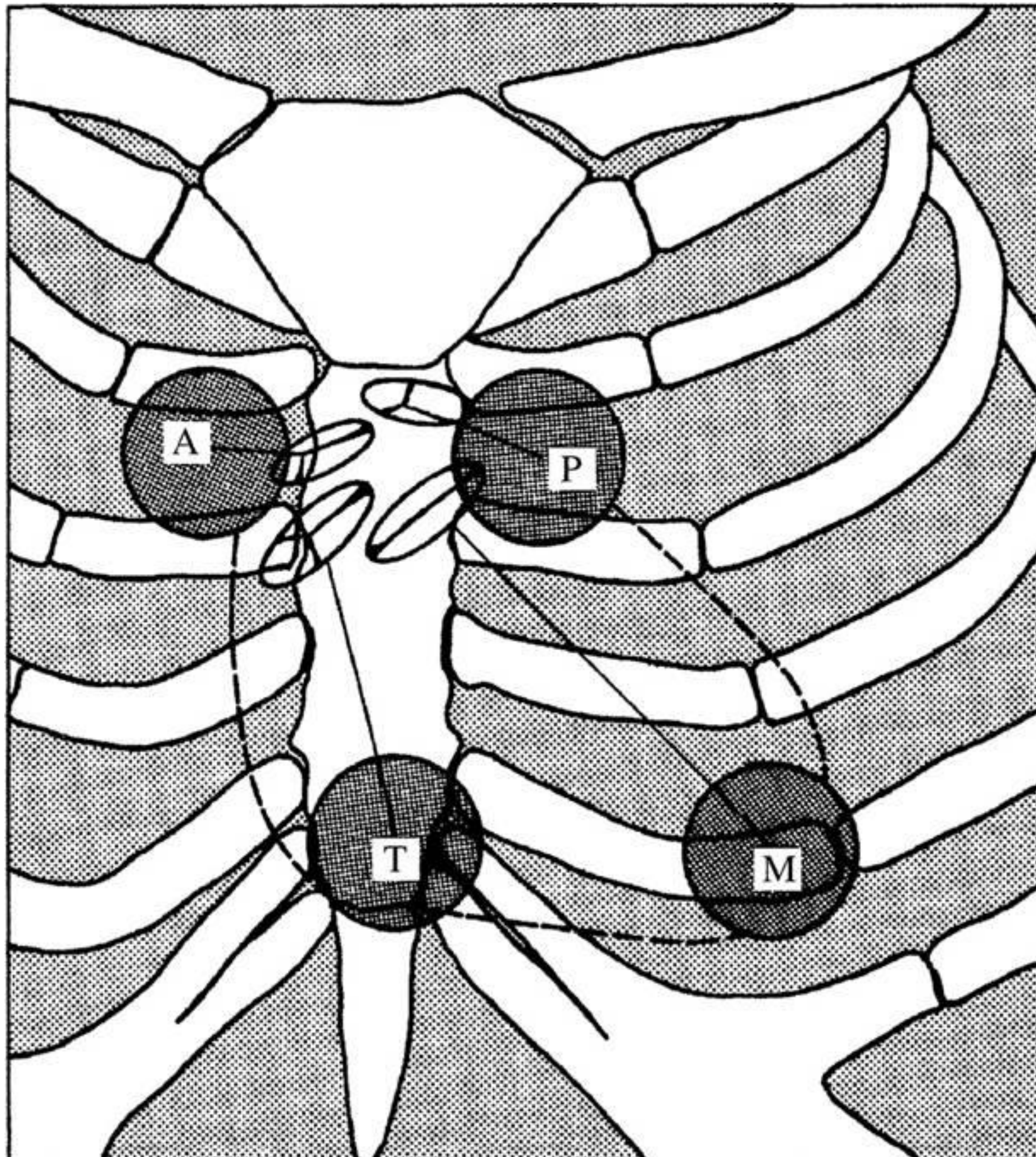
Murmurs

- Most murmurs are developed by turbulence in rapidly moving blood.
- Murmurs during the early systolic phase are common in children, and they are normally heard in nearly all adults after exercise.
- Abnormal murmurs may be caused by stenoses and insufficiencies (leaks) at the aortic, pulmonary, and mitral valves.
- They are detected by noting the time of their occurrence in the cardiac cycle and their location at the time of measurement.
- Example: http://www.blaufuss.org/tutorial/index2.html

Auscultation techniques

- Heart sounds travel through the body from the heart and major blood vessels to the body surface.
- Because of the acoustical properties of the transmission path, sound waves are attenuated and not reflected. The largest attenuation of the wavelike motion occurs in the most compressible tissues, such as the lungs and fat layers.
- There are optimal recording sites for the various heart sounds, sites at which the intensity of sound is the highest because the sound is being transmitted through solid tissues or through a minimal thickness of inflated lung.
- There are four basic chest locations at which the intensity of sound from the four valves is maximized.

Figure 7.16 Auscultatory areas on the chest A, aortic; P, pulmonary; T, tricuspid; and M, mitral areas. (From A. C. Burton, Physiology and Biophysics of the Circulation, 2nd ed. Copyright © 1972 by Year Book Medical Publishers, Inc., Chicago. Used by permission.)



Frequency Response

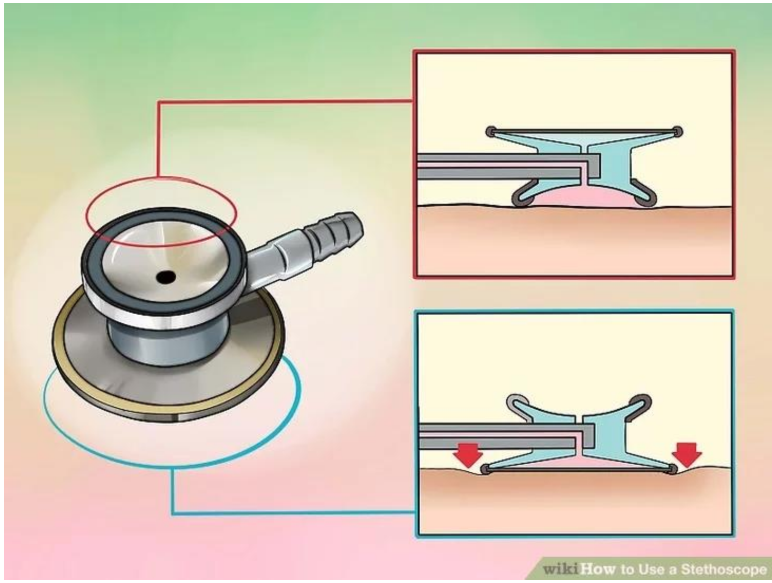
- Heart sounds and murmurs have extremely small amplitudes, with frequencies from 0.1 to 2000 Hz.
- Two difficulties may result.
  - At the low end of the spectrum (below about 20 Hz), the amplitude of heart sounds is below the threshold of audibility.
  - The high-frequency end is normally quite perceptible to the human ear, because this is the region of maximal sensitivity.
  - However, if a phonocardiogram is desired, the recording device must be carefully selected for high frequency-response characteristics.
  - That is, a light-beam, ink-jet, or digital-array recorder would be adequate, whereas a standard pen strip-chart recorder would not.

Stethoscope

- Stethoscopes are used to transmit heart sounds from the chest wall to the human ear.
- Some variability in interpretation of the sounds stems from the user's auditory acuity and training.
- Stethoscope acoustics reflected the acoustics of the human ear.
- Younger individuals have revealed slightly better responses to a stethoscope than their elders.
- The mechanical stethoscope amplifies sound because of a standing-wave phenomenon that occurs at quarter-wavelengths of the sound.

How does Stethoscope Work?

- The diaphragm is the bottom side pictured in the image above. It basically is a plastic sheet that transmits vibrations from your skin and delivers them via the tubing to the listener’s ears. It is this side you have to use to hear medium to high-pitched sounds.
- On the other hand the bell-side is just a chamber that forms between the chestpiece and your patient’s chest. The change in volume of this chamber as a result of for example heart beats causes sound waves to travel via the tubing to the listener’s ear. Use this side for low-pitched sounds.



•Mechanical stethoscope has an uneven frequency response, with many resonance peaks.
•These investigators emphasized that the critical area of the performance of a stethoscope (the clinically significant sounds near the listener’s threshold of hearing) may be totally lost if the stethoscope attenuates them as little 3 dB.

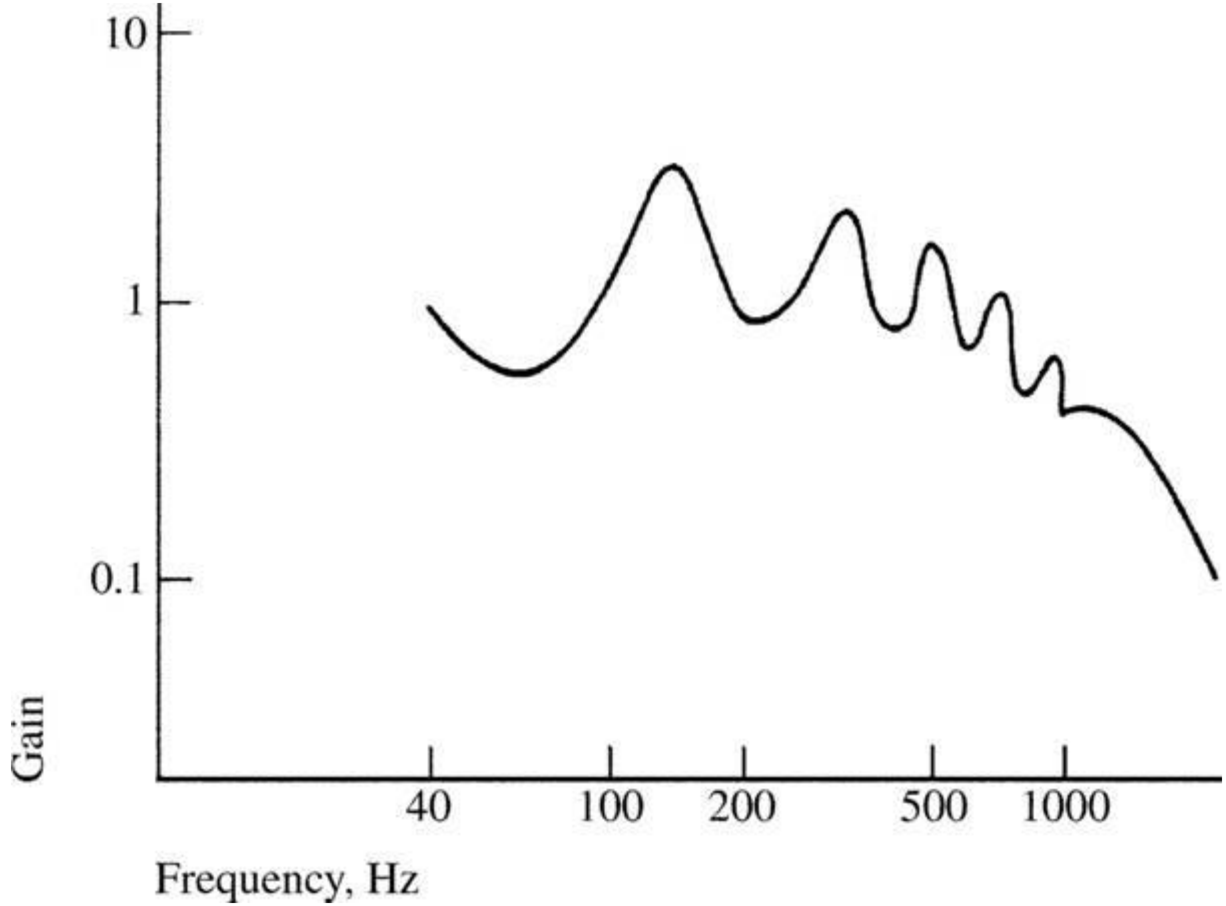


Figure 7.17 The typical frequency-response curve for a stethoscope can be found by applying a known audiofrequency signal to the bell of a stethoscope by means of a headphone-coupler arrangement. The audio output of the stethoscope earpiece was monitored by means of a coupler microphone system. (From P. Y. Ertel, M. Lawrence, R. K. Brown, and A. M. Stern, Stethoscope Acoustics I, "The Doctor and his Stethoscope." Circulation 34, 1966; by permission of American Heart Association.)

Issues with stethoscopes

- When the stethoscope chest piece is firmly applied, low frequencies are attenuated more than high frequencies. The diaphragm becomes taut with pressure, thereby causing an attenuation of low frequencies.
- Loose-fitting earpieces cause additional problems, because the leak that develops reduces the coupling between the chest wall and the ear, with a consequent decrease in the listener's perception of heart sounds and murmurs.
- Stethoscopes are also useful for listening to the sounds caused by air flow obstruction or lung collapse
- Electronic stethoscopes have selectable frequency-response characteristics ranging from the ‘‘ideal’’ flat-response case and selected bandpasses to typical mechanical stethoscope responses. Physicians, however, have not generally accepted these electronic stethoscopes, mainly because they are unfamiliar with the sounds heard with them.

Indirect Measurement of blood pressure

- Indirect measurement of blood pressure is an attempt to measure intra-arterial pressures noninvasively.
- The most standard manual techniques employ either the palpation or the auditory detection of the pulse distal to an occlusive cuff.
- Sphygmomanometer consisting of an inflatable cuff for occlusion of the blood vessel, a rubber bulb for inflation of the cuff, and either a mercury or an aneroid manometer for detection of pressure
- The occlusive cuff is inflated until the pressure is above systolic pressure and then is slowly bled off (2 to 3 mm Hg/s) (0.3 to 0.4 kPa/s).
- When the systolic peaks are higher than the occlusive pressure, the blood spurts under the cuff and causes a palpable pulse in the wrist (Riva–Rocci method).

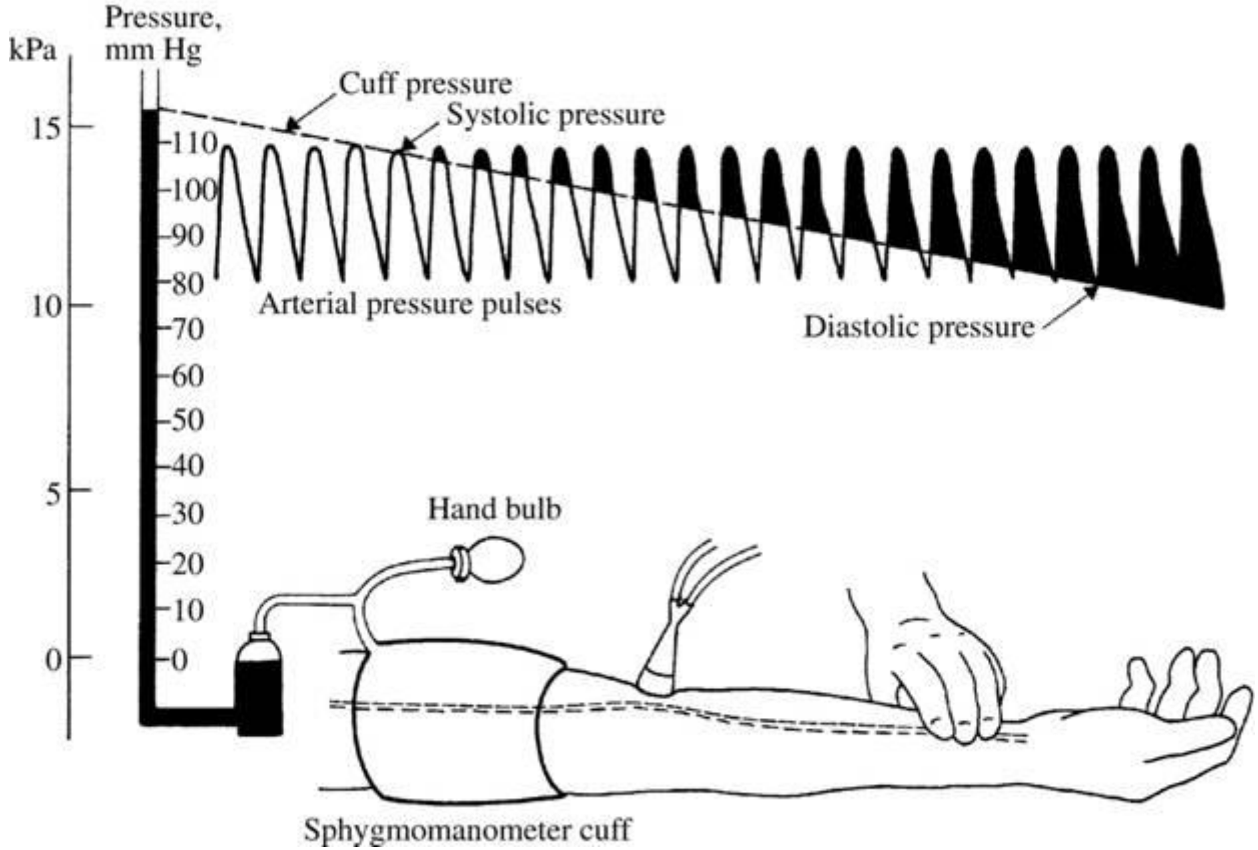
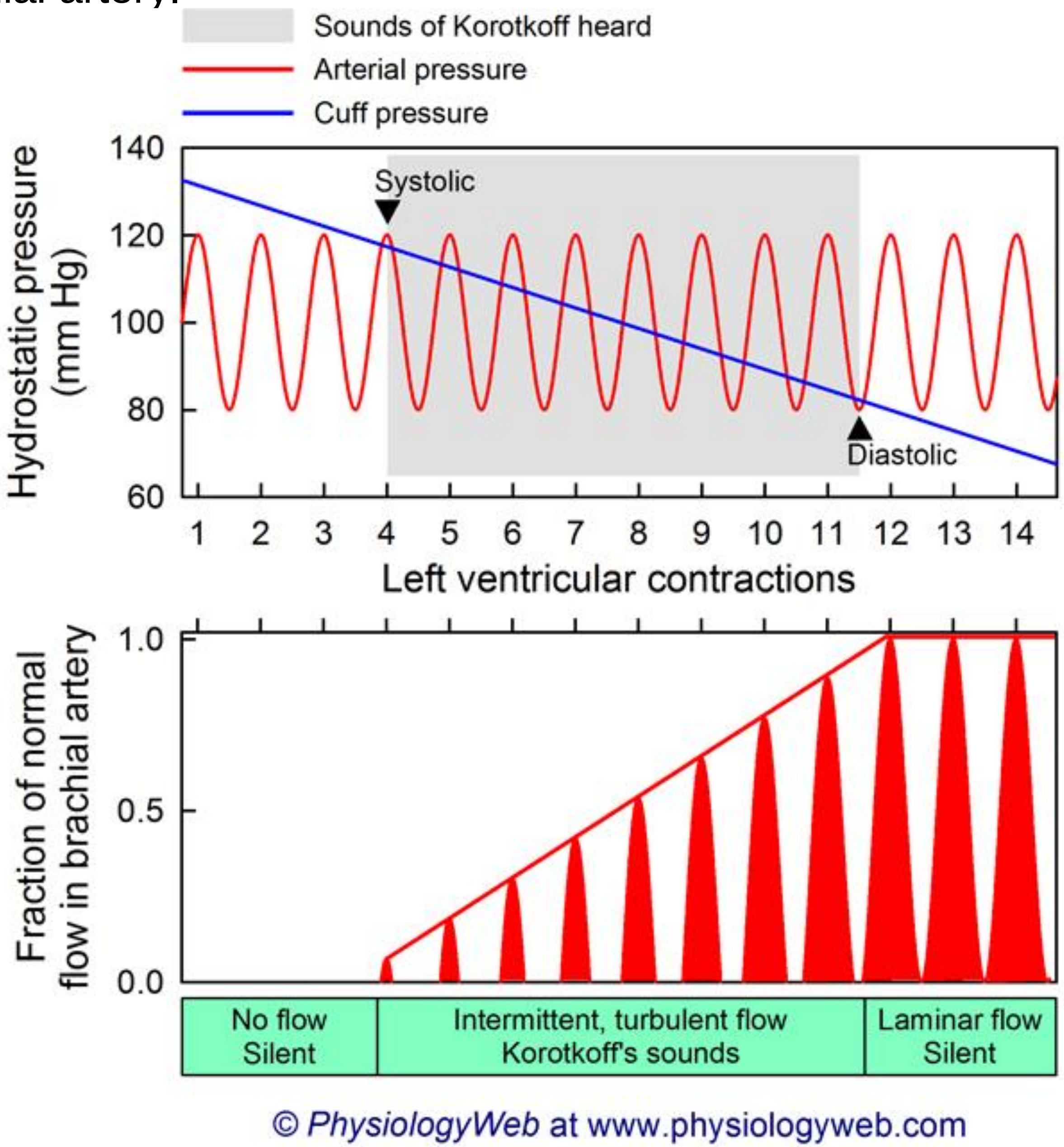
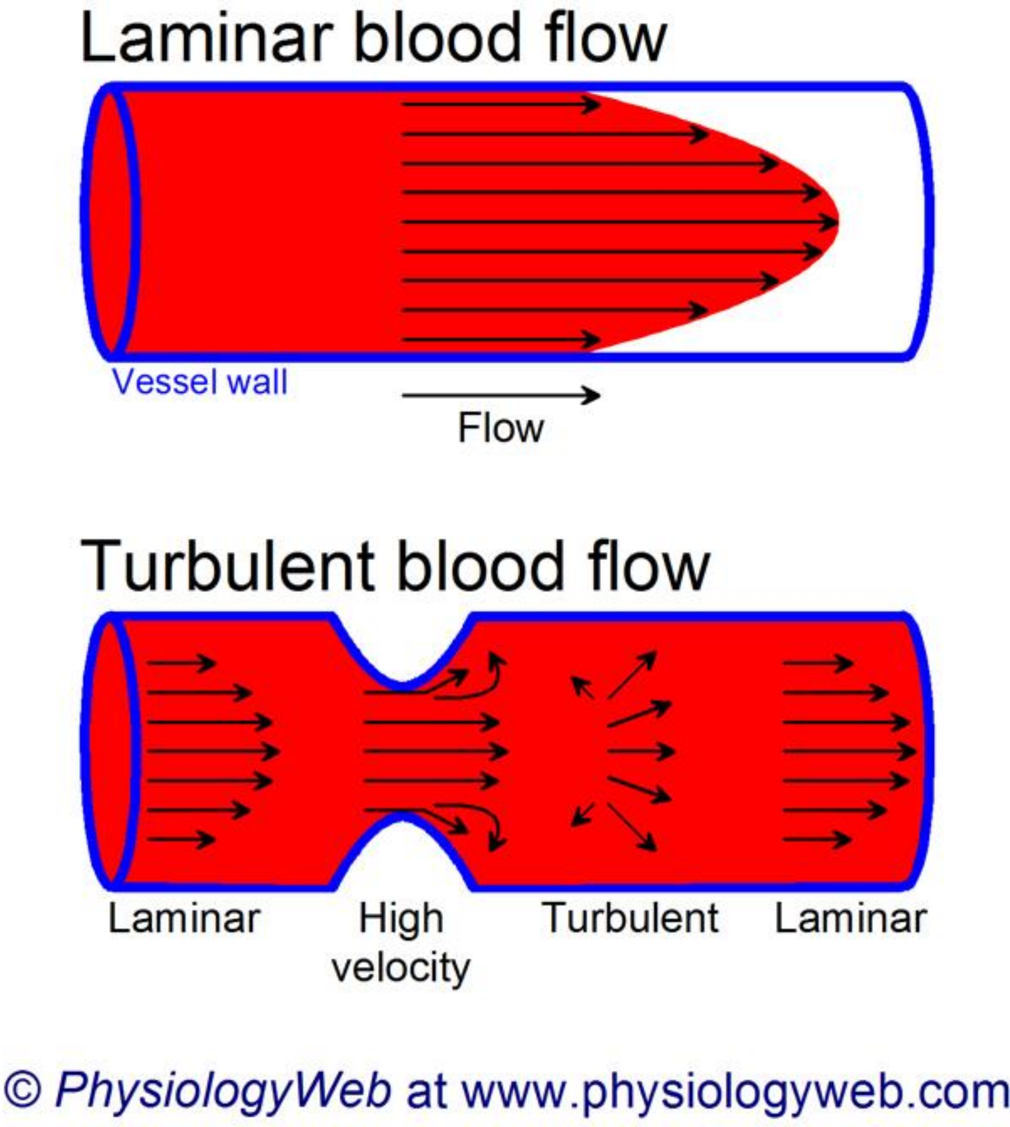


Figure 7.20 Typical indirect blood-pressure measurement system The sphygmomanometer cuff is inflated by a hand bulb to pressure above the systolic level. Pressure is then slowly released, and blood flow under the cuff is monitored by a microphone or stethoscope placed over a downstream artery. The first Korotkoff sound detected indicated systolic pressure, whereas the transition from muffling to silence brackets diastolic pressure. (From R.F. Rushmer, *Cardiovascular Dynamics*, 3rd ed., 1970. Philadelphia: W.B. Saunders Co. Used with permission.)

- The pressure in the cuff (blue line in top panel) is initially raised to a value above the expected arterial systolic pressure (red line in top panel). This will ensure complete obstruction of flow in the brachial artery.
- The cuff pressure is then gradually reduced at a rate of 2-3 mm Hg per second. At all cuff pressures above the systolic pressure, flow in the brachial artery remains obstructed. However, as soon as the cuff pressure falls below that of the peak systolic pressure, a small volume of blood is forced through the obstruction. The vessel constriction caused by the pressure cuff causes flow of this volume of blood to be turbulent. The turbulent flow causes a tapping sound known as the Korotkoff's sound, which can be heard by the stethoscope.

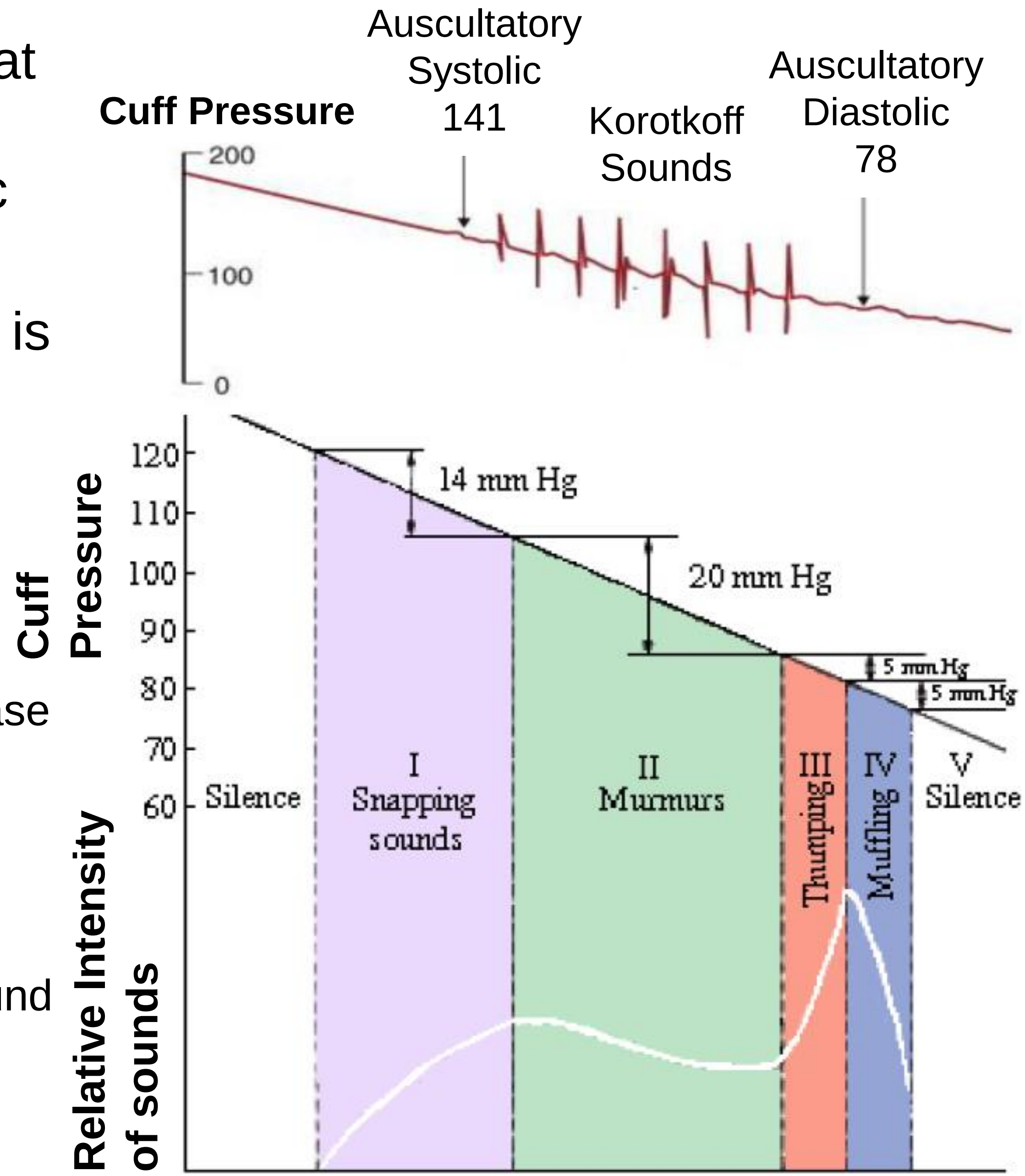


- Laminar flow refers to streamline movement of blood. In laminar flow, blood flows in layers which move parallel to the long axis of the blood vessel (straight arrows parallel with the vessel long axis). Close to the vessel wall, an infinitely thin layer of blood in contact with the wall is stationary (i.e., does not flow). The next layer in contact with this layer has a low velocity. As the layers extend toward the vessel interior, their velocity increases.
- Despite the pulsatile nature of flow in arteries, laminar blood flow is silent.
- Constriction of the vessel, or obstruction of the vessel lumen, disrupts laminar flow and leads to turbulent blood flow. At the point of constriction, blood flow velocity increases, but small eddies lead to flow in directions other than parallel to the long axis of the vessel. Such current eddies lead to turbulence.
- Turbulent blood flow is noisy and can be heard by using a stethoscope placed over the artery at or distal to the point of constriction or obstruction.



Korotkoff Sounds

- The manometer pressure at the first detection of the pulse indicates the systolic pressure.
- As the pressure in the cuff is decreased, the audible Korotkoff sounds pass through five phases.
  - I Initial “tapping” sounds (systolic pressure).
  - II The tapping sounds increase in intensity but are less well defined in time
  - III The loudest phase, more akin to a thump than a tap
  - IV A much more muffled sound
  - V Silence – no Korotkoff sounds (diastolic pressure).



Issues

- Take several measurements, because normal respiration and vasomotor waves modulate the normal blood-pressure levels.
- No accurate pressures for infants and hypotensive patients.
- Using an occlusive cuff of the correct size is important if the clinician is to obtain accurate results. The pressure applied to the artery wall is assumed to be equal to that of the external cuff. However, the cuff pressure is transmitted via interposed tissue. With a cuff of sufficient width and length, the cuff pressure is evenly transmitted to the underlying artery.
- The cuff should be placed at heart level to avoid hydrostatic effects.
- Auscultatory technique is simple and requires minimum equipment.
- Cannot be used in a noisy environment, whereas the palpation technique can.
- The hearing acuity of the user must be good for low frequencies from 20 to 300 Hz, the bandwidth required for these measurements.

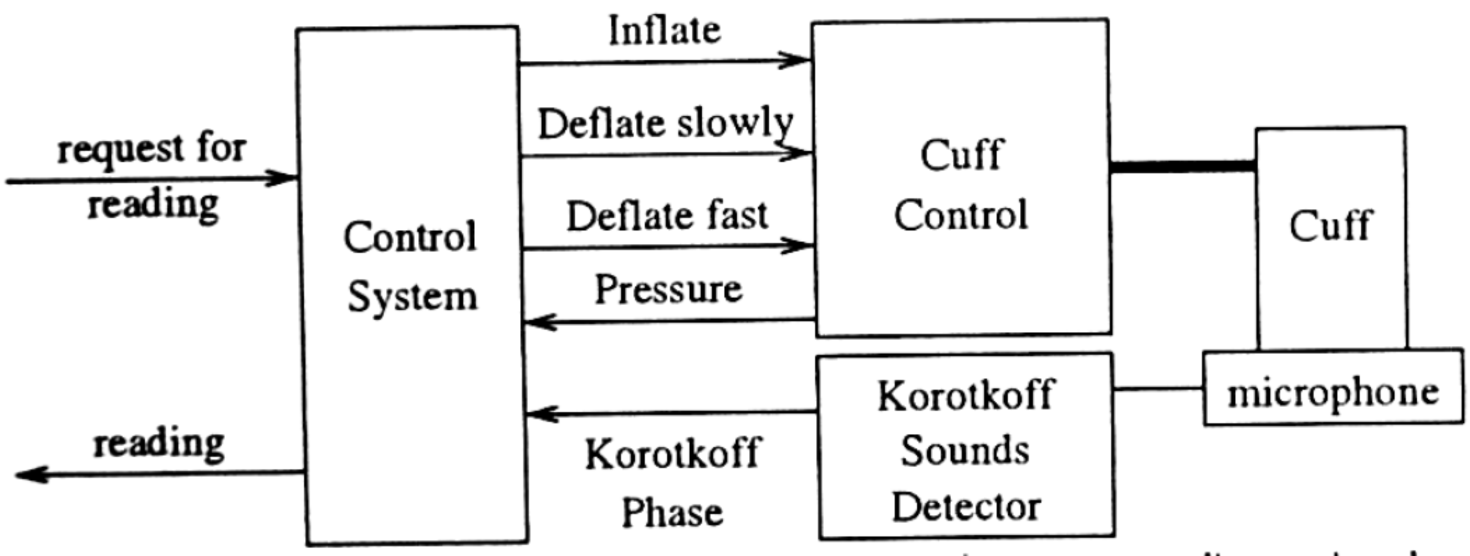
- Bellville and Weaver (1969) have determined the energy distribution of the Korotkoff sounds for normal patients and for patients in shock. When there is a fall in blood pressure, the sound spectrum shifts to lower frequencies. The failure of the auscultation technique for hypotensive patients may be due to low sensitivity of the human ear to these low-frequency vibrations (Geddes,1970).
- There is a common misconception that normal human blood pressure is 120/80, meaning that the systolic value is 120 mm Hg (16 kPa) and that the diastolic value is 80 mm Hg (10.7 kPa). This is not the case. A careful study (by Master et al., 1952) showed that the age and sex of an individual determine the ‘‘normal value’’ of blood pressure.

Design Of An Automatic Indirect Blood Pressure Measurement System.

- The basic technique involves an automatic sphygmomanometer that inflates and deflates an occlusive cuff at a predetermined rate. A sensitive detector is used to measure the distal pulse or cuff pressure.
- ultrasonic, piezoelectric, photoelectric, electroacoustic, thermometric, electrocardiographic, rheographic, and tissue-impedance devices.

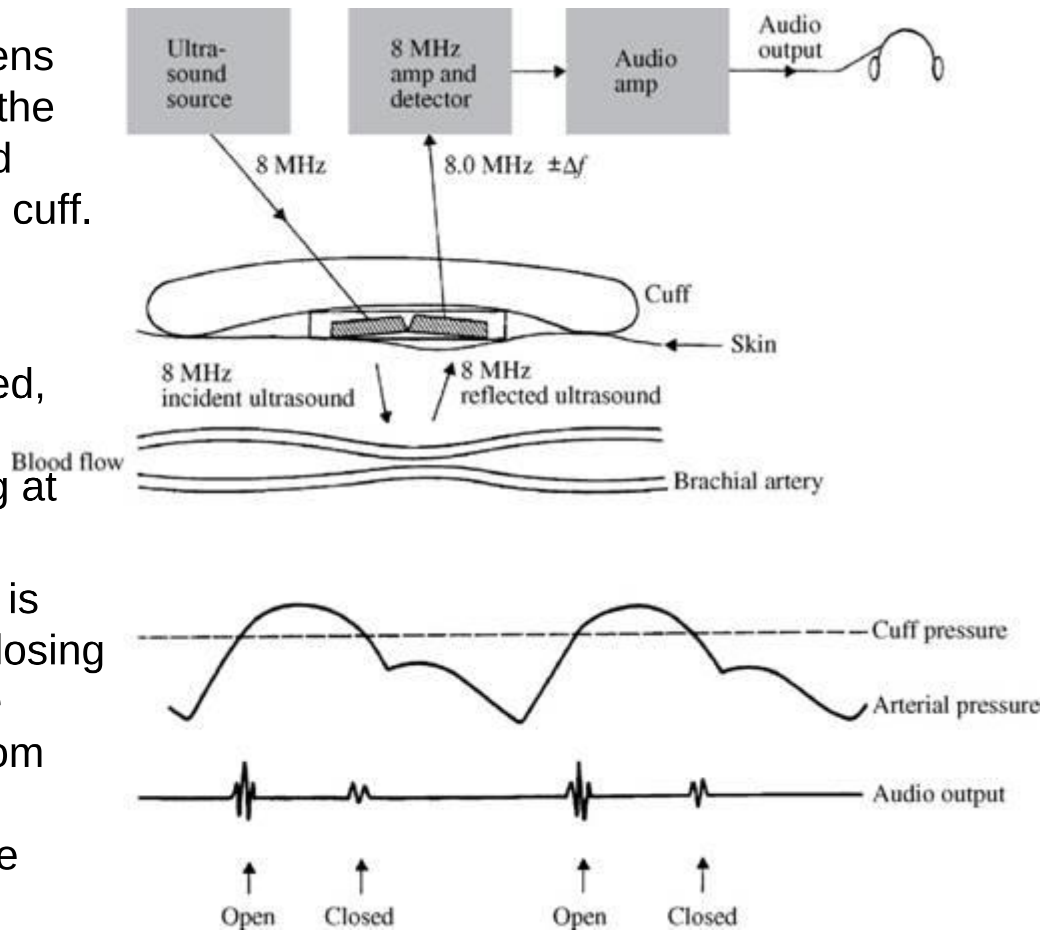
First Method

- The first technique employs an automated auscultatory device wherein a microphone replaces the stethoscope.
- The cycle of events that takes place begins with a rapid (20 to 30mmHg/s) (2.7 to 4 kPa/s) inflation of the occlusive cuff to a preset pressure about 30 mm Hg higher than the suspected systolic level. The flow of blood beneath the cuff is stopped by the collapse of the vessel.
- Cuff pressure is then reduced slowly (2 to 3 mm Hg/s) (0.3 to 0.4 kPa/s).
- The first Korotkoff sound is detected by the microphone, at which time the level of the cuff pressure is stored.
- The muffling and silent period of the Korotkoff sounds is detected, and the value of the diastolic pressure is also stored. After a few minutes, the instrument displays the systolic and diastolic pressures and recycles the operation.
- The presence of other sounds (e.g. the noise of the heart beating) confuses the analysis.



Ultrasonic determination of blood pressure

- Figure shows the placement of the compression cuff over two small transmitting and receiving ultrasound crystals (8 MHz) on the arm.
- The Doppler ultrasonic transmitted signal is focused on the vessel wall and the blood. The reflected signal (shifted in frequency) is detected by the receiving crystal and decoded.
- The difference in frequency, in the range of 40 to 500 Hz, between the transmitted and received signals is proportional to the velocity of the wall motion and the blood velocity.
- As the cuff pressure is increased above diastolic but below systolic, the vessel opens and closes with each heartbeat, because the pressure in the artery oscillates above and below the applied external pressure in the cuff.
- The opening and closing of the vessel are detected by the ultrasonic system.
- As the applied pressure is further increased, the time between the opening and closing decreases until they coincide. The reading at this point is the systolic pressure.
- Conversely, when the pressure in the cuff is reduced, the time between opening and closing increases until the closing signal from one pulse coincides with the opening signal from the next. The reading at this point is the diastolic pressure, which prevails when the vessel is open for the complete pulse.



Advantages/Disadvantages

- Advantages - can be used with infants and hypotensive individuals and in high-noise environments.
- Disadvantage - movements of the subject's body cause changes in the ultrasonic path between the sensor and the blood vessel.
- Complete reconstruction of the arterial-pulse waveform is also possible via the ultrasonic method.
- A timing pulse from the ECG signal is used as a reference.
- The clinician uses the pressure in the cuff when the artery opens versus the time from the ECG R wave to plot the rising portion of the arterial pulse.
- Conversely, the clinician uses the cuff pressure when the artery closes versus the time from the ECG R wave to plot the falling portion of the arterial pulse

Oscillometry

- This method predates the method of Korotkoff but was not originally as popular. However, it is now the standard method for automated Blood Pressure measurement.
- In 1885 the French physiologist Marey observed that, if he placed a patient’s arm in a pressure chamber then the pressure of the chamber would fluctuate with the pulse and the magnitude of the fluctuation would vary with the pressure of the chamber.
- It is now known that these fluctuations correspond to the occluding effect on the artery of pressure applied uniformly to the arm and that the same effect can be observed in the pressure of an occluding cuff.
- Measures the amplitude of oscillations that appear in the cuff pressure signal which are created by expansion of the arterial wall each time blood is forced through the artery.

Oscillometric method

- Using this method, it is therefore possible to design a device for measuring Blood Pressure non−invasively in which it is not necessary to analyse the Korotkoff sounds and **only a cuff needs to be attached** to the patient.
- A pressure slightly above systolic pressure is detected by determining the shift from small-amplitude oscillations at cuff pressure slightly above systolic pressure and when the cuff pressure begins to increase amplitude (Point 1).
- As the cuff continues to deflate, the amplitude of the oscillations increases reaching a maximum, and then decreases as the cuff pressure is decreased to zero.
- Point 2 is the maximum cuff-pressure oscillation which is essentially true mean arterial pressure. Since there is no apparent transition in the oscillation amplitude as cuff pressure passes diastolic pressure, algorithmic methods are used to predict diastolic pressure.

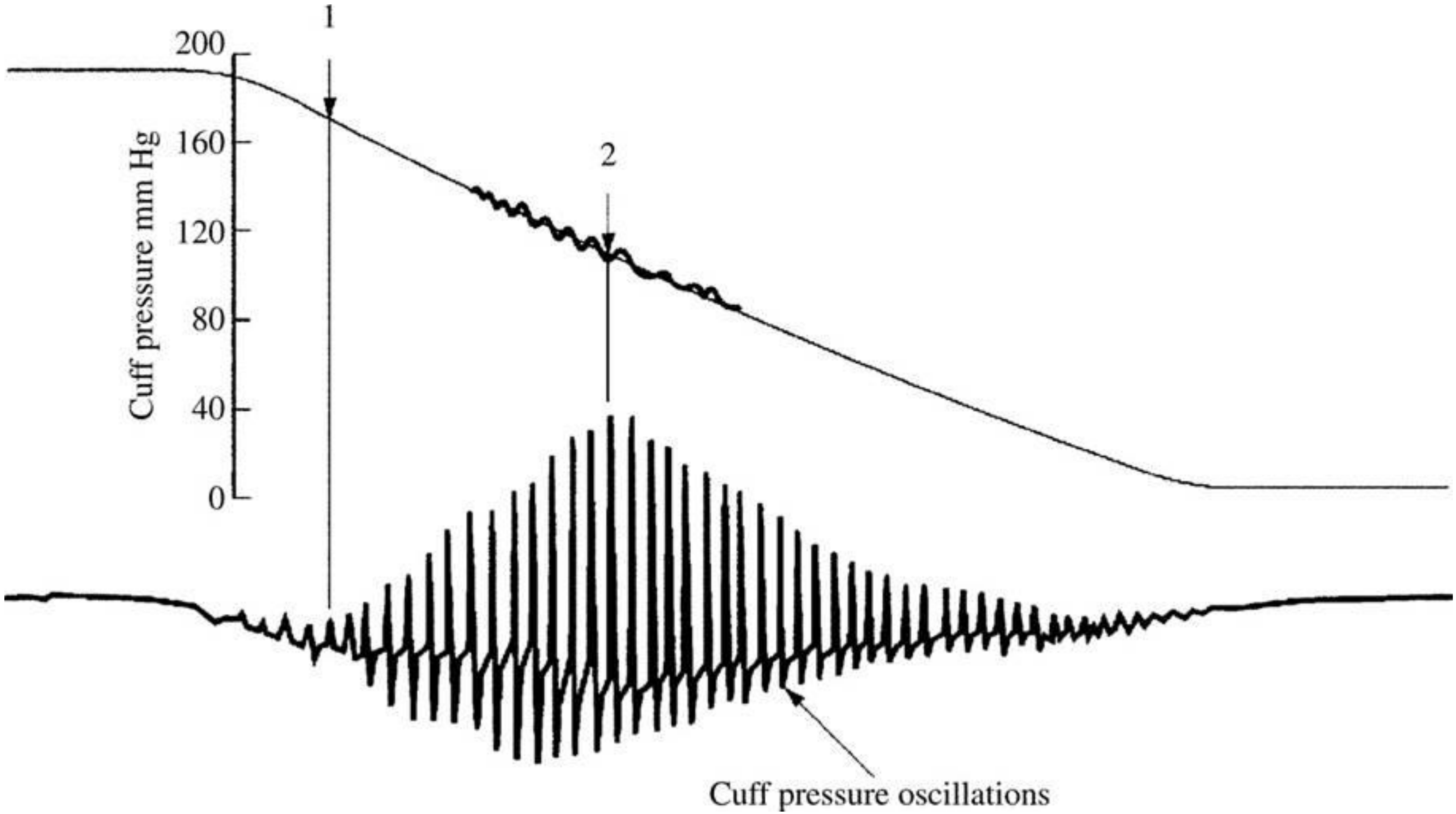
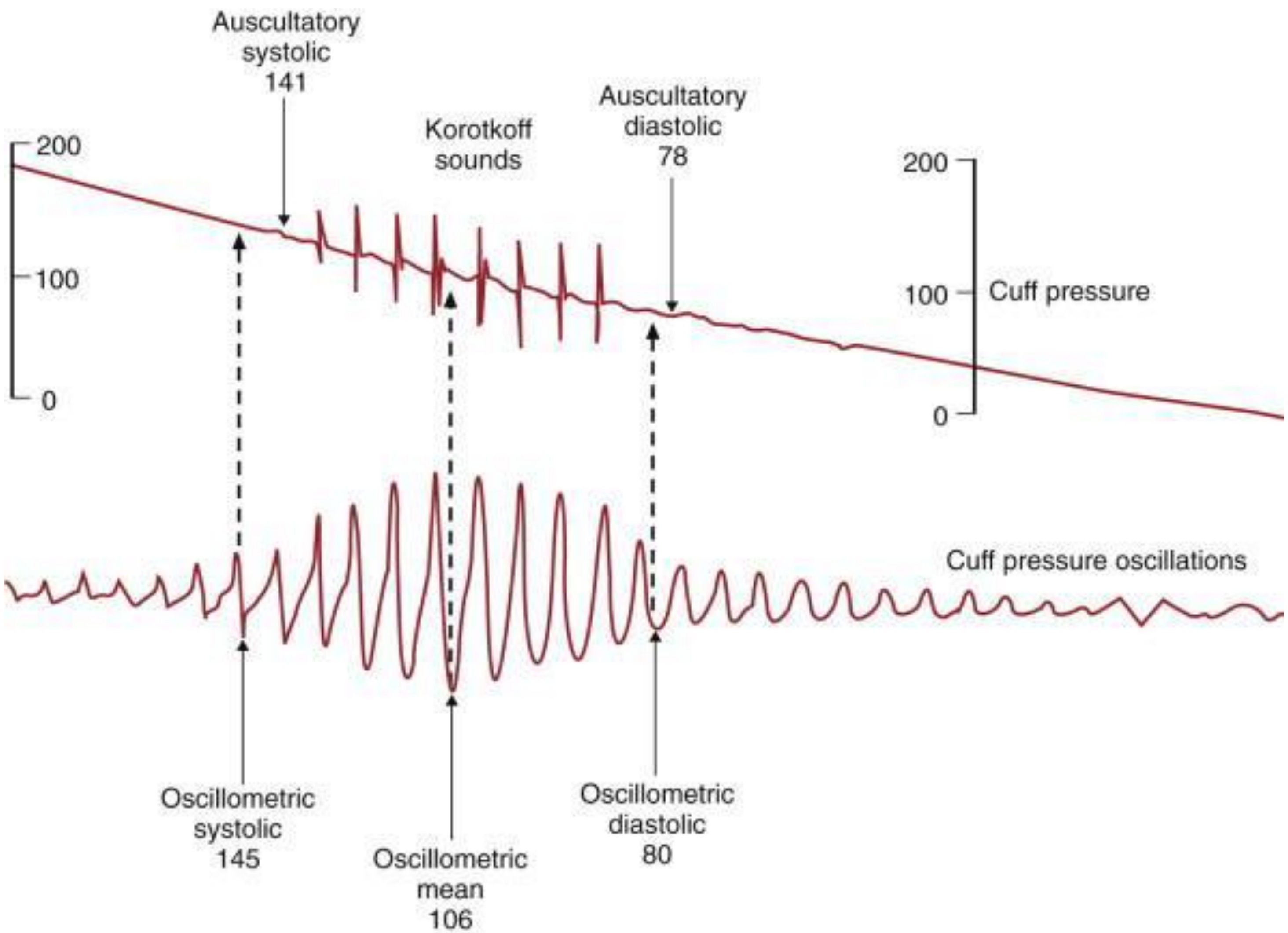


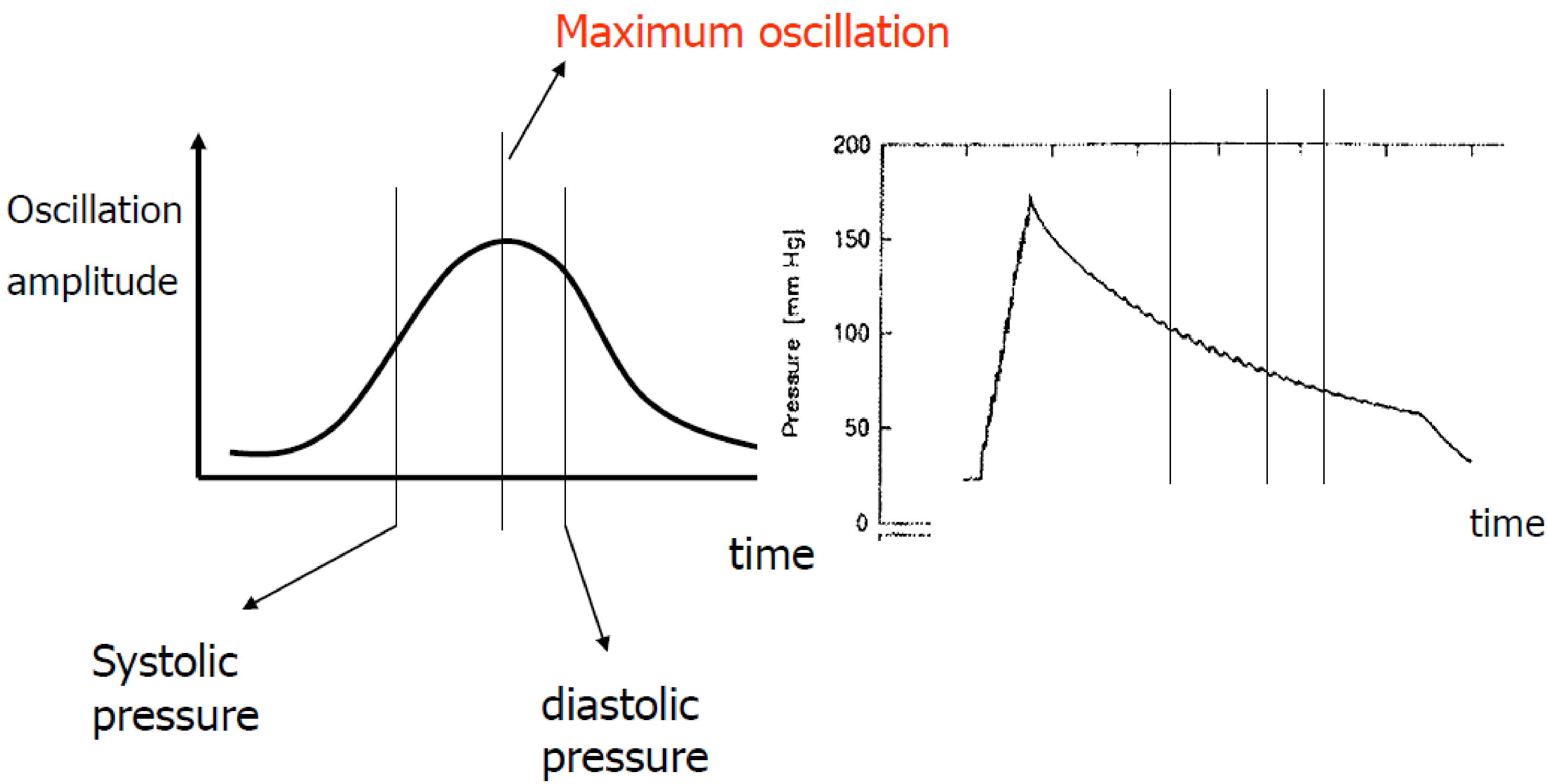
Figure 7.22 The oscillometric method A compression cuff is inflated above systolic pressure and slowly deflated. Systolic pressure is detected (Point 1) where there is a transition from small amplitude oscillations (above systolic pressure) to increasing cuff-pressure amplitude. The cuff-pressure oscillations increase to a maximum (Point 2) at the mean arterial pressure.

- The pressure at which the oscillations have their maximum amplitude is the Mean Arterial Pressure (MAP).
- Systolic pressure and diastolic pressure are estimated.



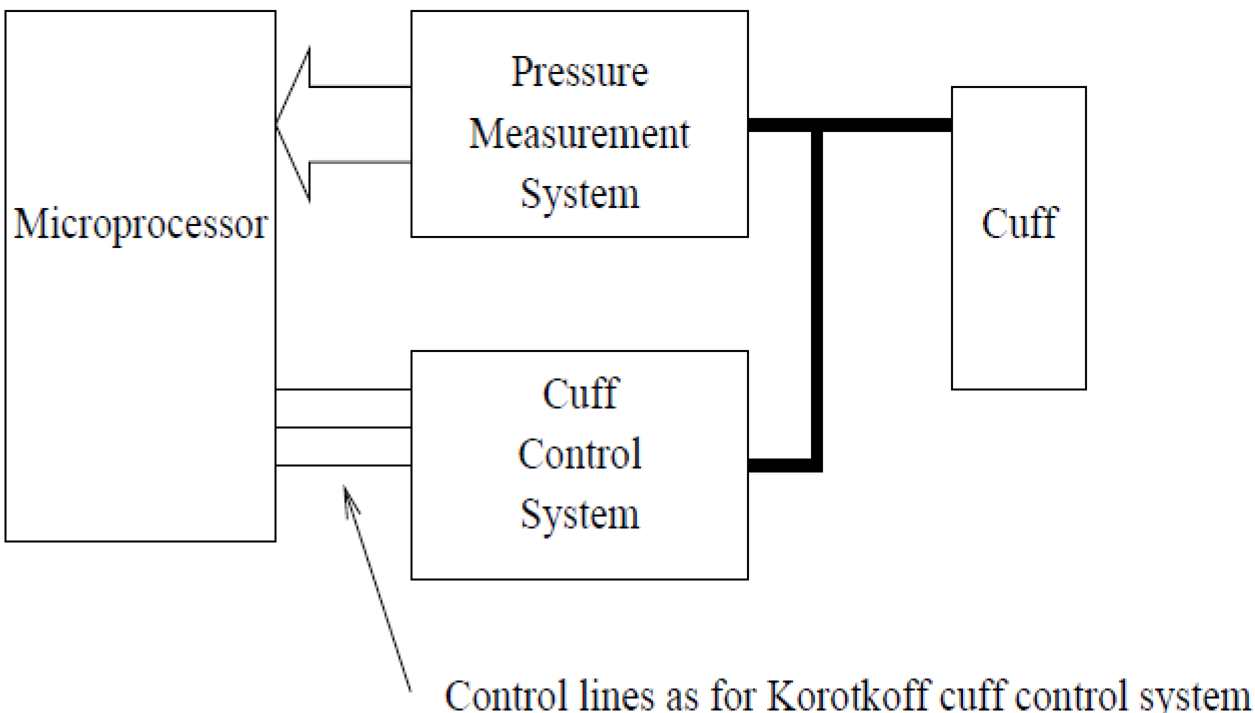
Empirical determination of systolic and diastolic pressures

- Systolic pressure = cuff pressure when the oscillation amplitude is 55% of the maximum amplitude
- Diastolic pressure = cuff pressure when the oscillation amplitude is 85% of the maximum amplitude



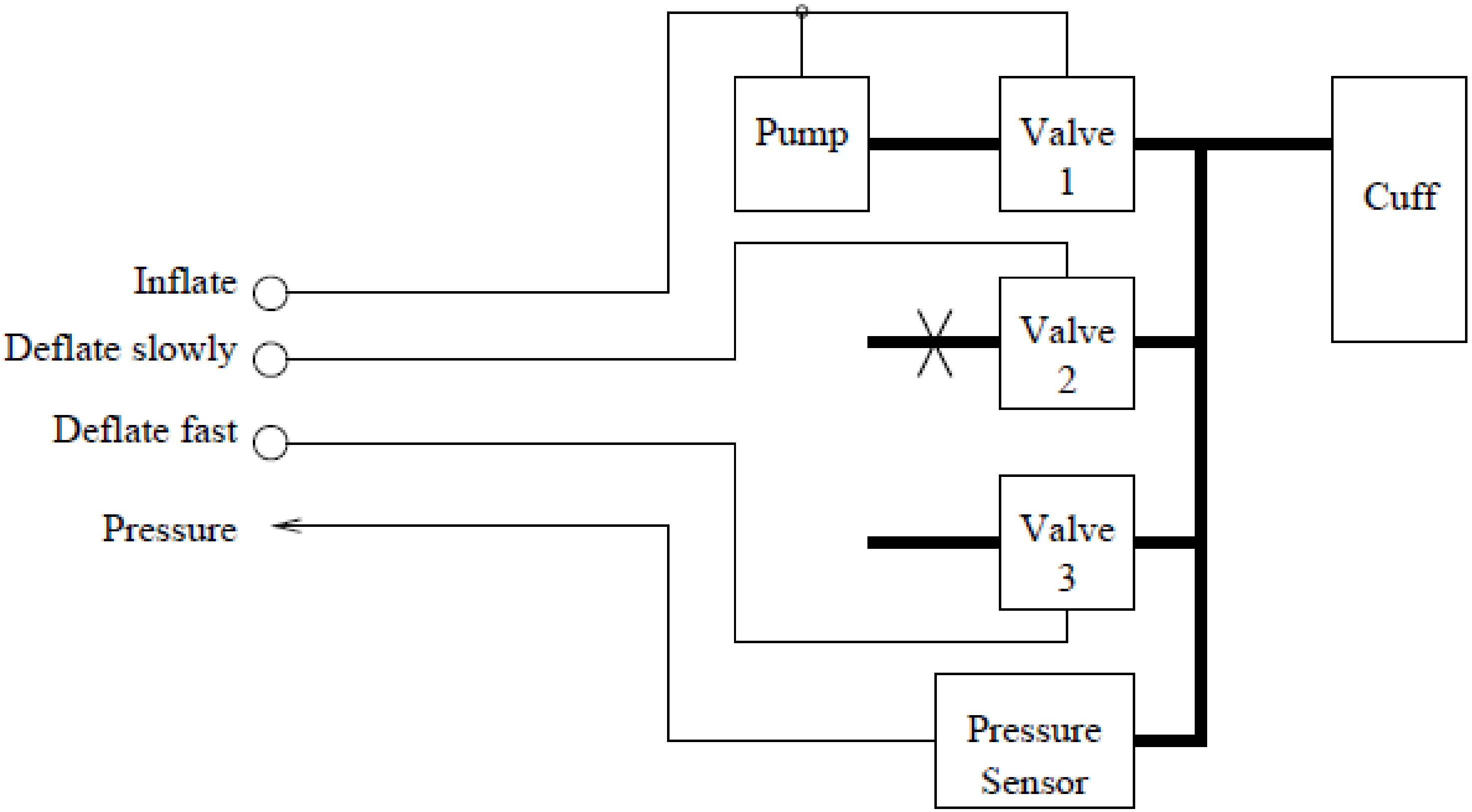
Overview of a system for Oscillometric Blood Pressure

- It is possible to design a system for measuring blood pressure non-invasively using oscillometry.
- The cuff control system developed for the method of Korotkoff sounds can be used and combined with a pressure measurement system.



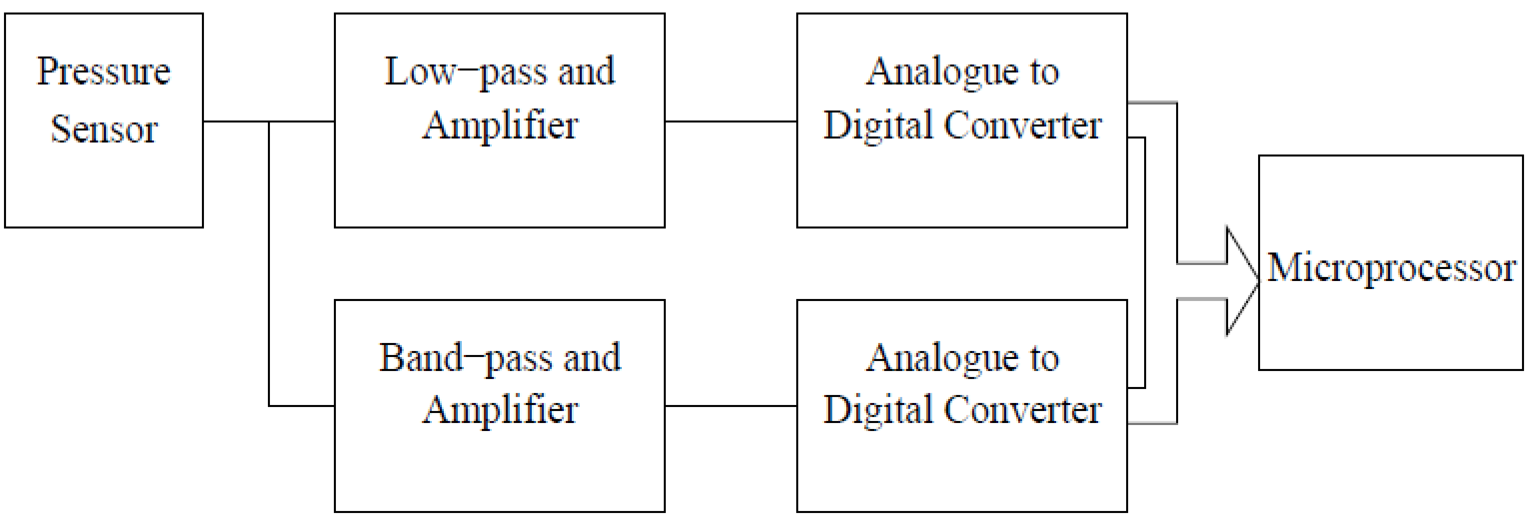
Cuff Control System

- The cuff is inflated (ie pressurised) by using a pump to blow air into it and so when cuff inflation is requested the pump is turned on and that valve is opened.
- When the cuff is sufficiently inflated, the control signal will be changed to "deflate slowly" and the valve between the pump and the motor will be shut to present unwanted air leakage.
- The second valve will be opened which allows a controlled slow leakage of air from the cuff.
- Finally, once the readings have been made, the cuff can be emptied of air and the final valve is opened to achieve this.



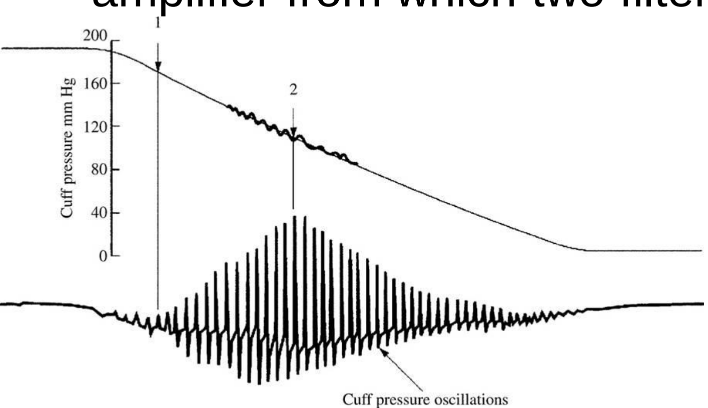
Pressure sensor

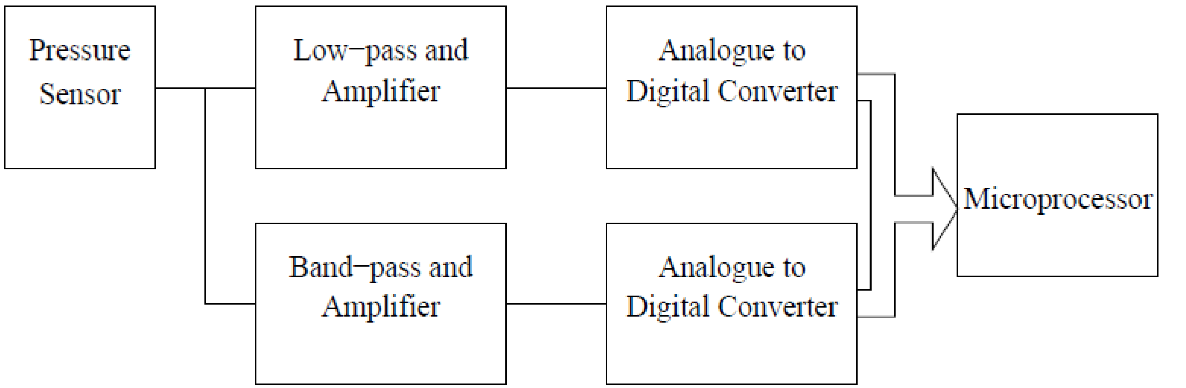
- Pressure sensors typically employ the piezo−resistive principle to convert pressure to an electrical signal.
- A silicon chip is micro−machined to give a diaphragm around which four resistors are diffused in a bridge configuration. Application of pressure to the diaphragm results in a change in the value of these resistors which creates a differential voltage output proportional to the applied pressure.



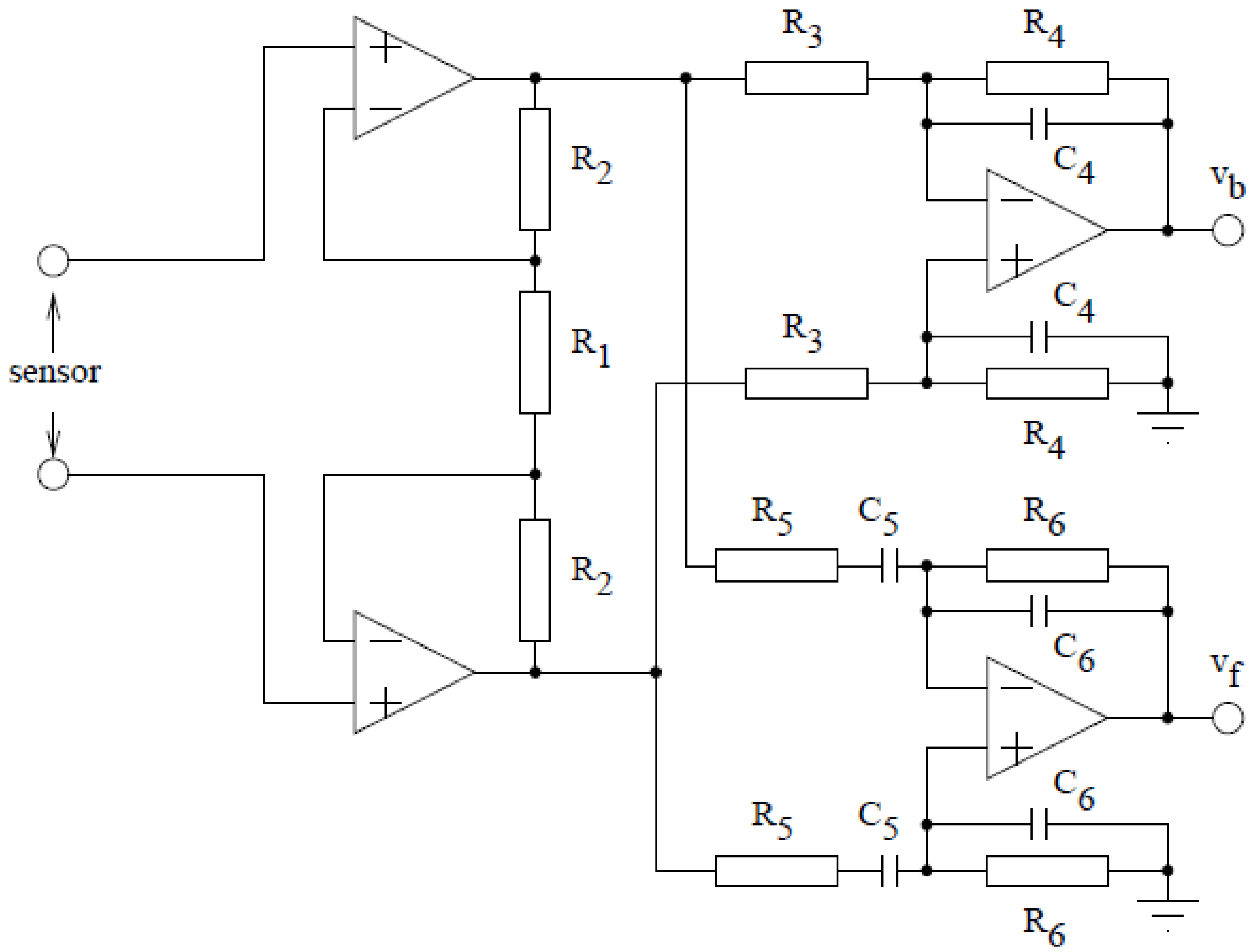
Pressure sensor

- There are two pieces of information in the pressure signal: the underlying pressure to which the cuff has been inflated (or deflated) and the fluctuations present on the signal.
- The underlying signal is a low frequency signal and can be extracted by passing the signal through a low−pass filter.
- The fluctuations, which are cardiac synchronous, can be extracted using a band−pass filter.
- Given that the outputs from the sensor are differential, differential amplifiers and filters are required here.
- it is essential that the circuit used has a near infinite input impedance because the sensors have a finite output impedance (approximately 5kW) which varies with the applied pressure.
- It is also inappropriate to drive two amplifiers directly from the sensor and so the sensor itself must be connected to a high input−impedance differential buffering amplifier from which two filters can be driven.



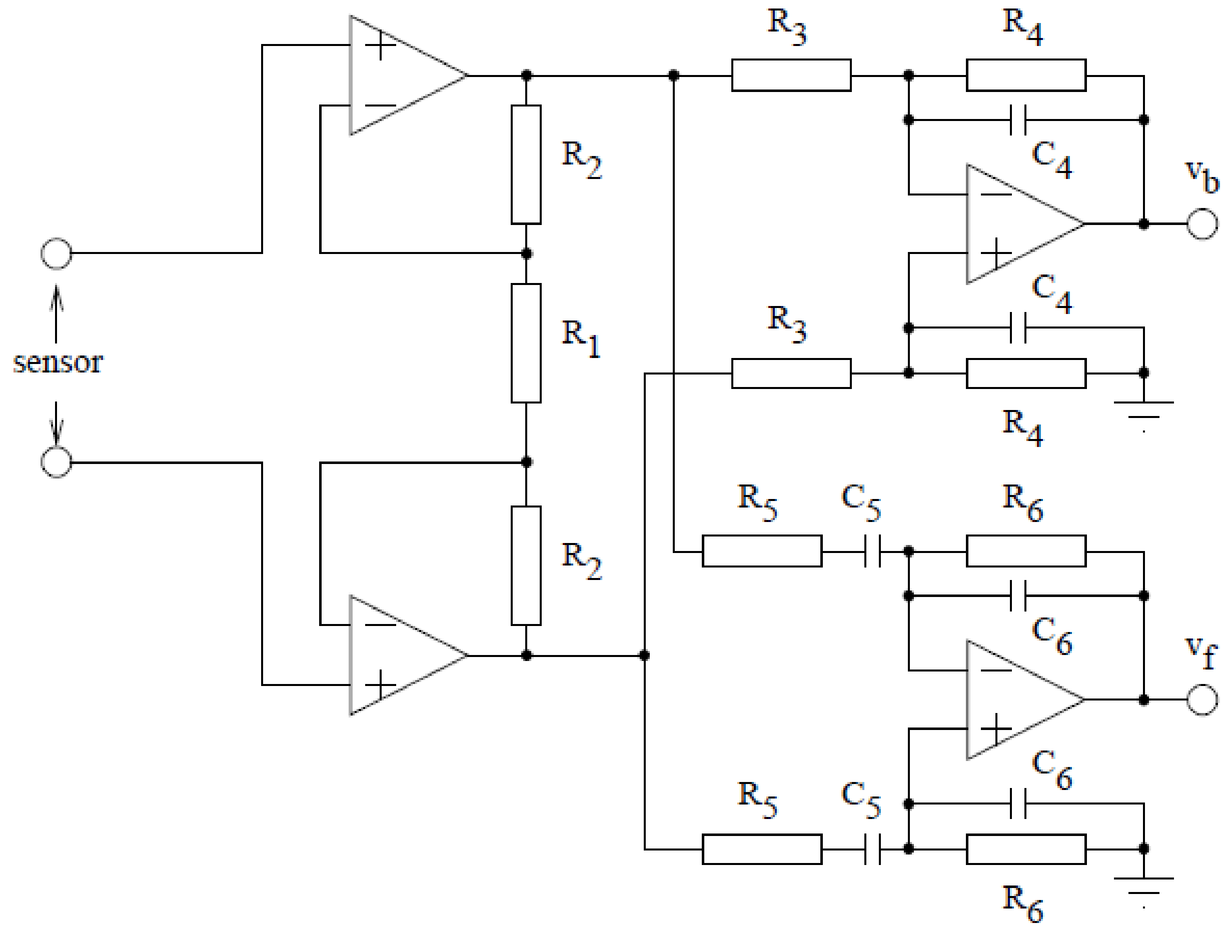


- This circuit is very similar to the circuit considered for silver−silver electrodes in the discussions of ECG circuitry above.
- It achieves a very high input impedance with good noise performance.
- Two second stage differential amplifiers form the low and band−pass filters and output two signals: a baseline signal, $\mathbf{v_b}$ and a fluctuations signal $\mathbf{v_f}$.



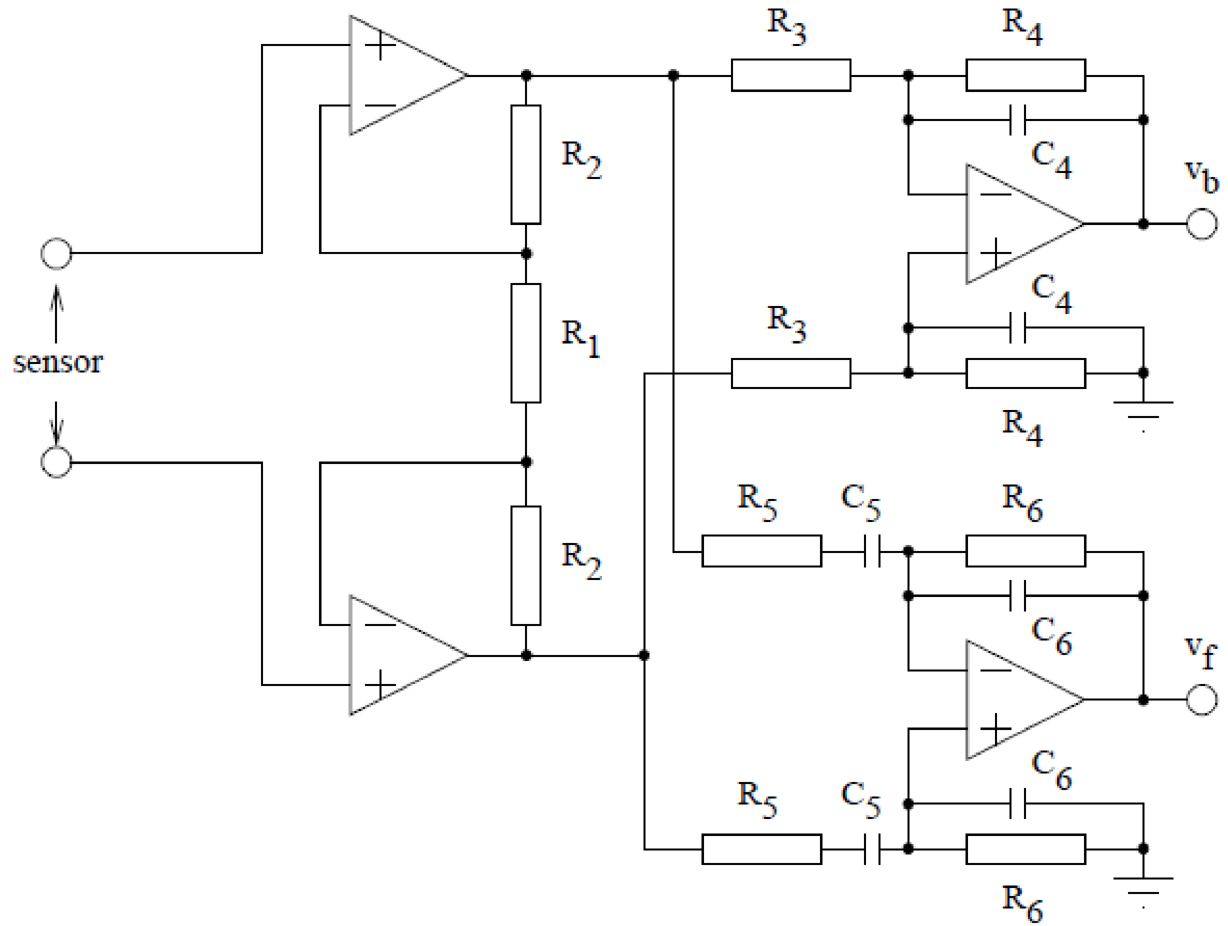
EXAMPLE

- A patient is attached to an oscillometric Blood Pressure device. The circuit diagram for processing the output of the pressure sensor prior to digitisation is given in Figure. The sensor which is attached to this circuit has a sensitivity of approximately 1 mV per mmHg. The two outputs, vb and vf are the baseline pressure signals and the fluctuations signal respectively. The baseline signal, vb, has an input range of 0−300 mV.
- Both the second stage outputs are digitised and to minimise the cost of manufacture they will both be digitised by the same device which has a 0−3 V input range.
- Given that the observed fluctuations are up to 6 mmHg, what gains should the two branches of the circuit have?



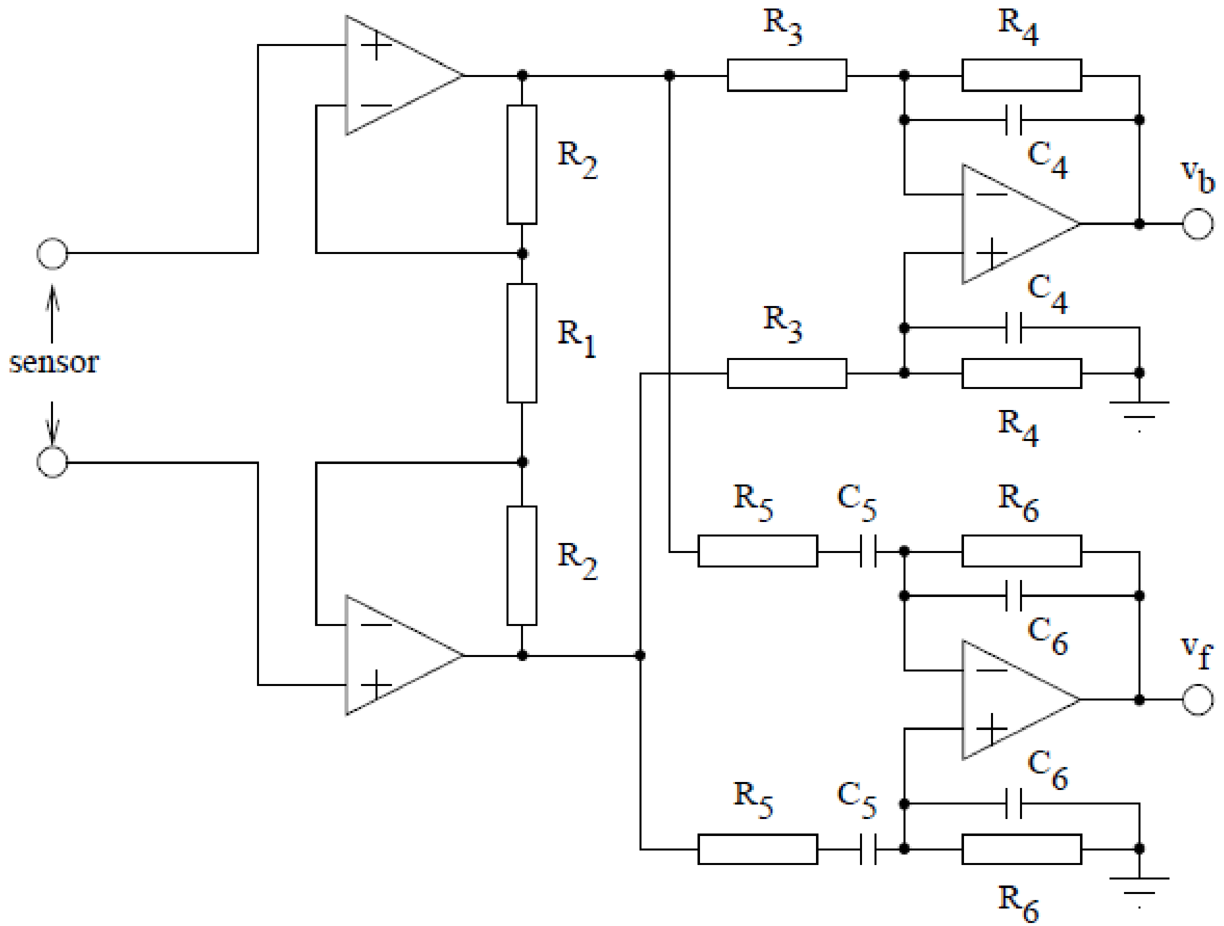
EXAMPLE

- Given R1 = 20 kΩ, R3 = 100 kΩ, R5 =10 kΩ, C6 = 22 nF. The op−amps which are to be used have a maximum practicable gain of 25. What should the pass−band gain be for the input circuit and the two second phase circuits to achieve the required gains? What value should R2 therefore be set to?



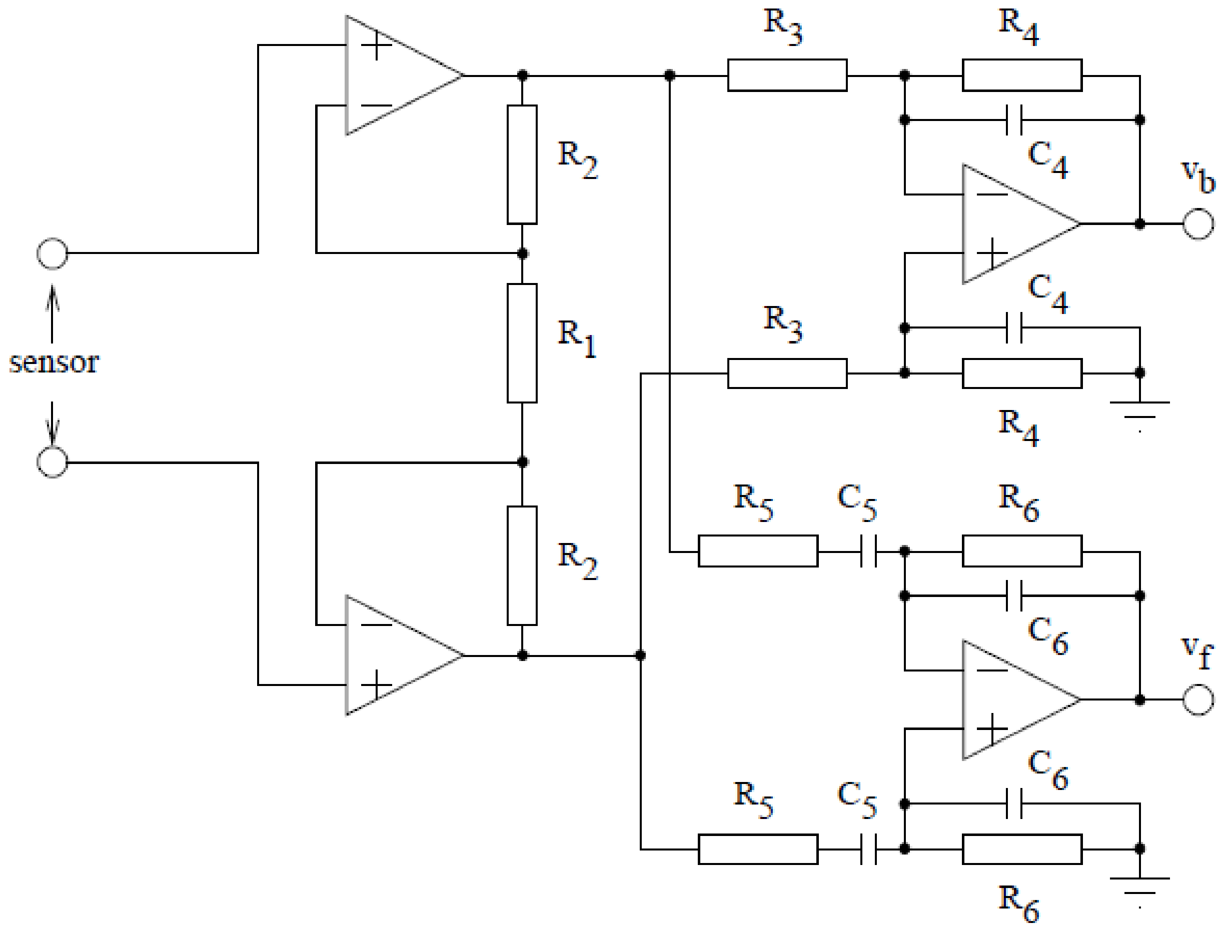
EXAMPLE

- What is the purpose of C4? What value should it and R4 therefore be set to given the decisions made so far? Sketch the resulting frequency response for v_b.
- R1 = 20 kΩ, R3 = 100 kΩ, R5 =10 kΩ, C6 = 22 nF, R2 = 200 kΩ



EXAMPLE

- The second circuit for vf is configured as a pass−band with cut-off frequencies 0.5 to 30 Hz. What purpose does the capacitor C5 serve? What values should C5 and R6 be set to? Sketch the resulting frequency response for vf and give the achieved gain for vf.
- R1 = 20 kΩ, R3 = 100 kΩ, R5 =10 kΩ, C6 = 22 nF, R2 = 200 kΩ



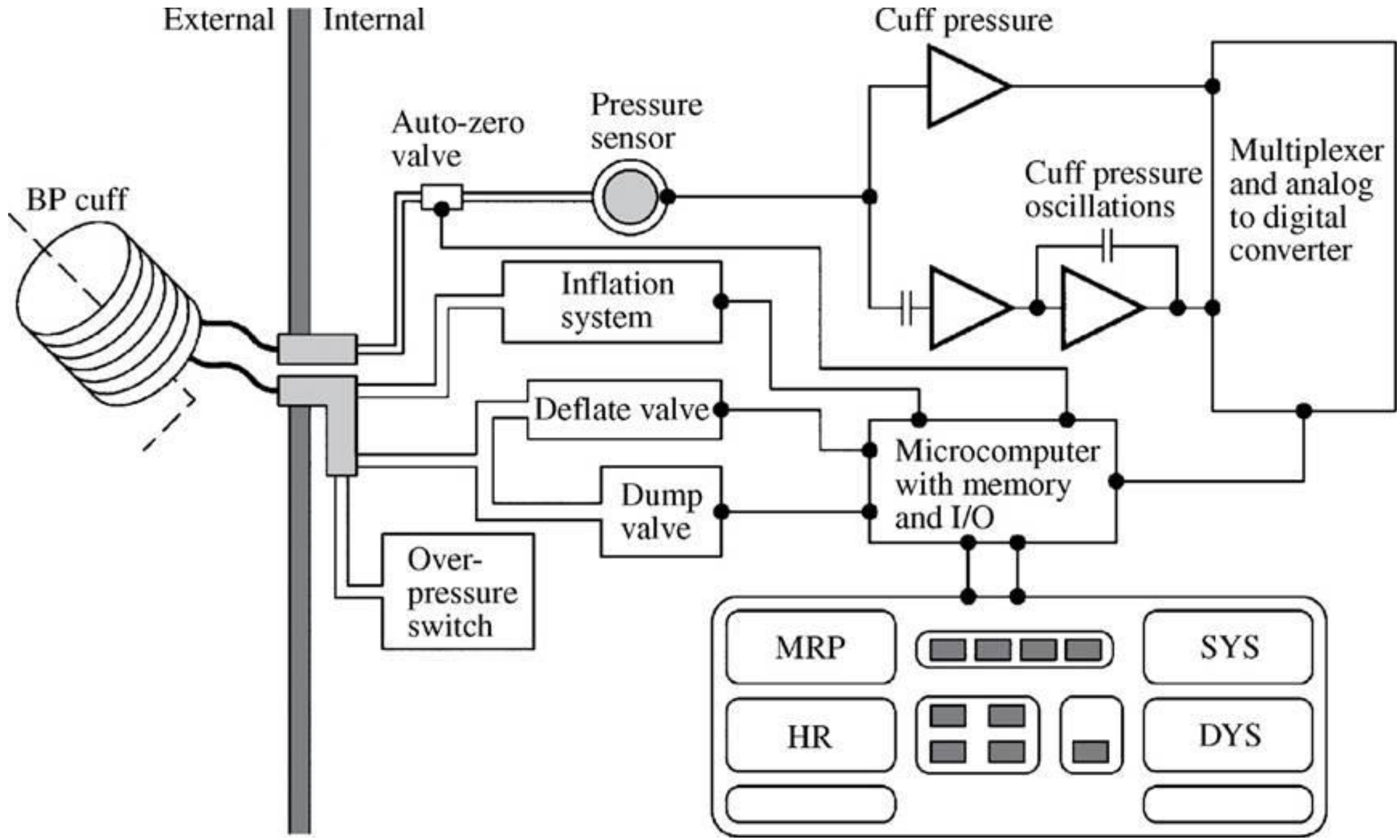


Figure 7.23 Block diagram of the major components and subsystems of an oscillometric blood-pressure monitoring device, based on the Dinamap unit, I/O = input/output; MAP = mean arterial pressure; HR = heart rate; SYS = systolic pressure; DYS = diastolic pressure. From Ramsey M III. Blood pressure monitoring: automated oscillometric devices, *J. Clin. Monit*. 1991, 7, 56–67.

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