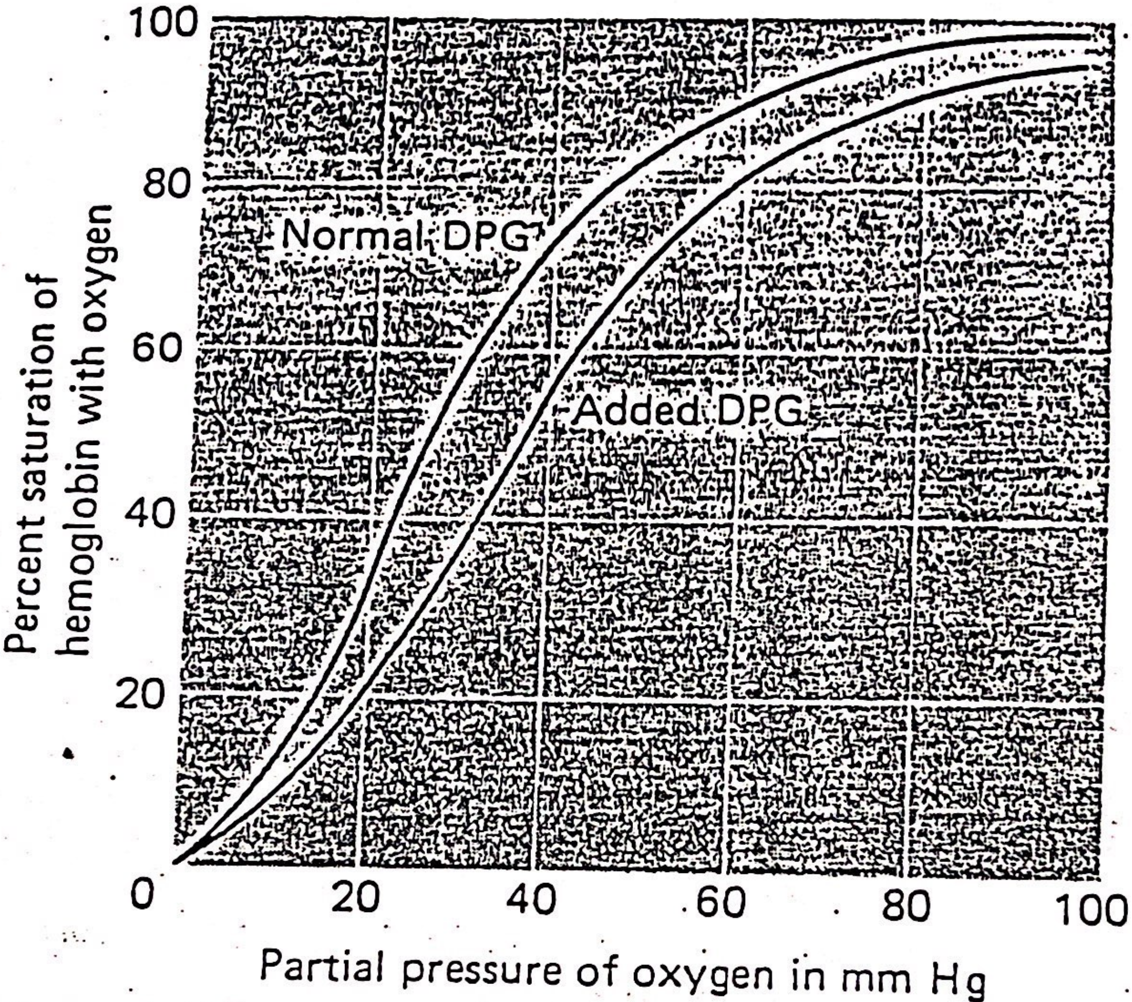



**Figure 17.17 Effect of 2,3-Diphosphoglycerate (DPG) on Oxygen Dissociation from Hemoglobin.** The formation of extra DPG in red blood cells, as occurs at high altitudes, shifts the dissociation curve to the right. In other words, DPG promotes the release of oxygen from hemoglobin. (Modified and reproduced with permission from J. H. Comroe, Jr., *Physiology of Respiration*, 2d ed., p. 185. Copyright © 1974 by Year Book Medical Publishers, Inc., Chicago.)

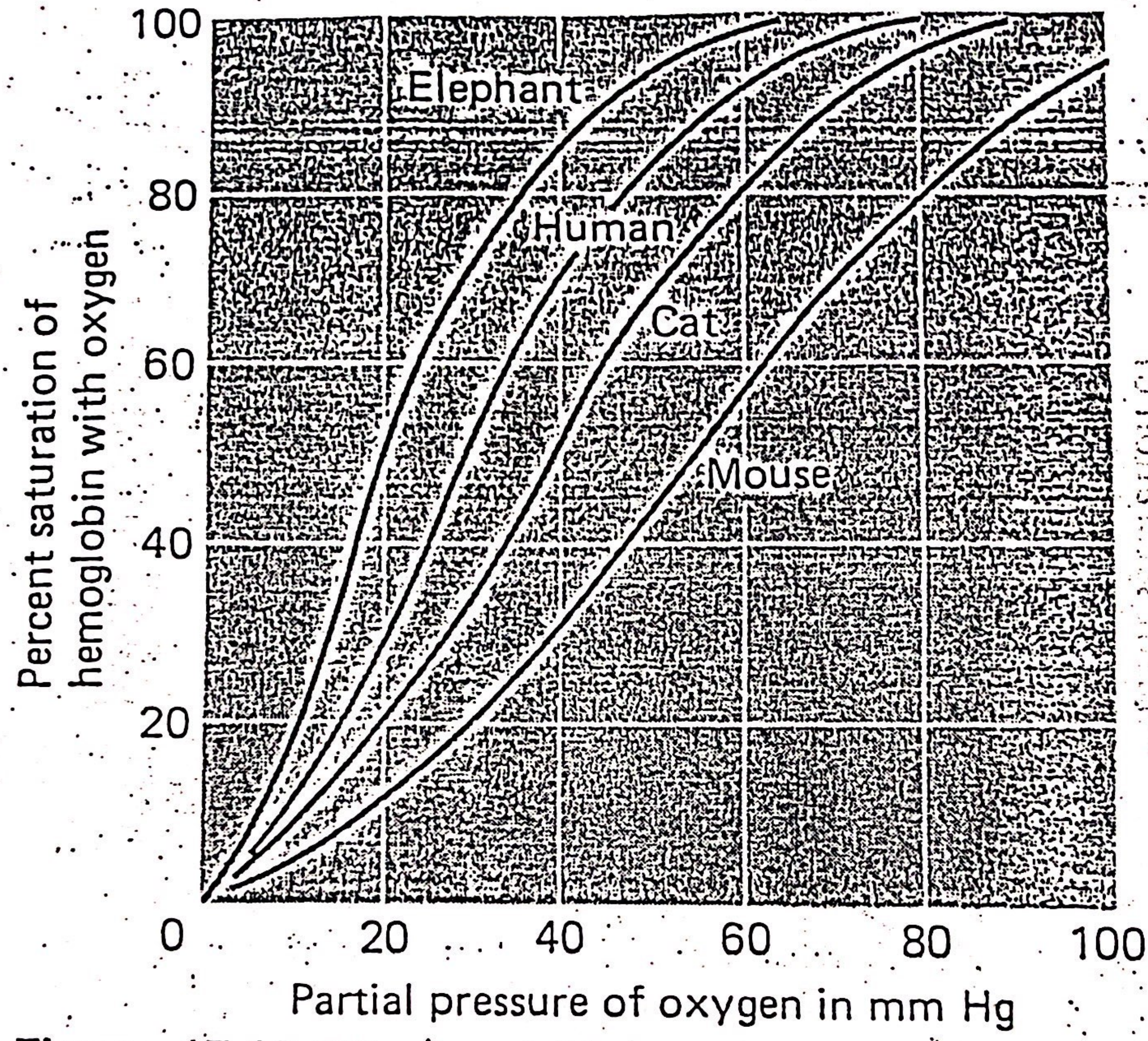
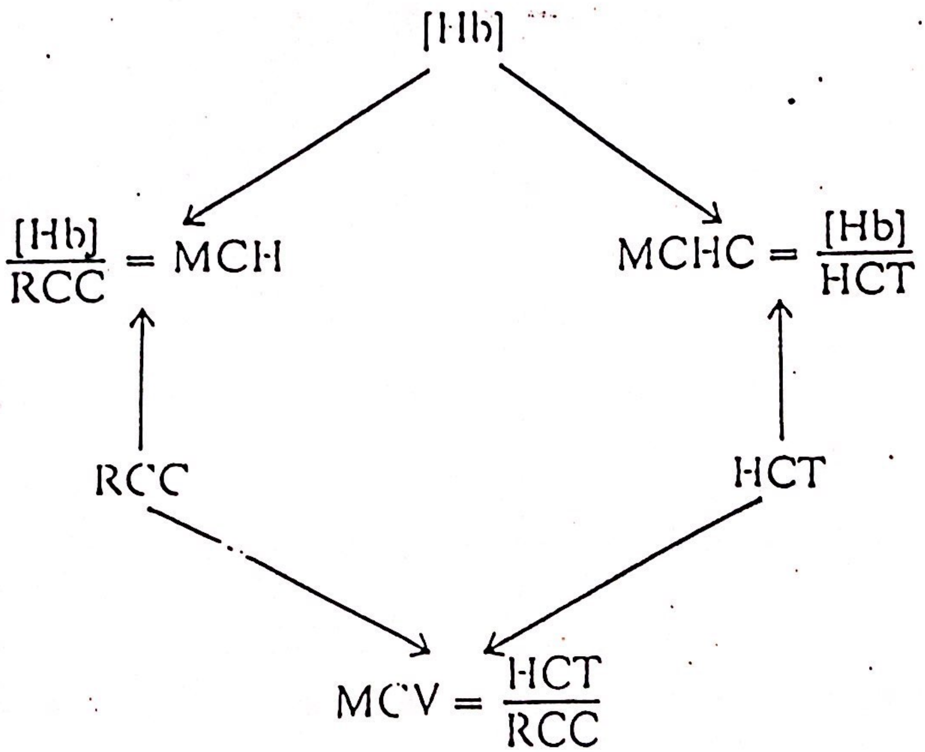



**Figure 17.18 Effects of Mammalian Size on Oxygen Dissociation from Hemoglobin.** Small mammals release oxygen more readily from hemoglobin than do large mammals. This difference is probably related to the greater need for oxygen in small mammals to support a greater heat production per unit of body weight. (Reprinted from K. Schmidt-Nielsen, *Federation Proceedings* 29 [1970]:1529.)

**Relationships between the erythrocyte parameters.** For the diagnostic evaluation of erythrocyte function it is usually necessary to measure three quantities: the *red cell count* RCC ($\mu l^{-1}$), the *hemoglobin concentration of the blood* [Hb] (g/l), and the *hematocrit* HCT. From these, three other characteristic parameters can be derived: the *mean corpuscular hemoglobin* MCH, the *mean corpuscular hemoglobin concentration* MCHC, and the *mean corpuscular volume* MCV. The relationships underlying these calculations are reflected directly in the definitions of the parameters and are summarized in the following diagram:




Given, for example, that RCC = $5 \cdot 10^6 \mu l$, [Hb] = 150 g/l and HCT = 0.45, the other parameters are as follows: MCH = 30 pg, MCHC = 333 g/l, and MCV = $0.09 \cdot 10^{-6} \mu l$ = 90 fl (femtoliters) = 90 $\mu m^3$ (the conversion among units is given on pp. 796f.).

* Values for Central Europe; for North America (according to Wintrobe) MCH = 29 pg

## Mean Corpuscular Hemoglobin (MCH)

The MCH indicates the average weight of hemoglobin in the red blood cell.

$$\text{MCH} = \frac{\text{Weight of hemoglobin in 1 } \mu\text{l of blood}}{\text{Number of red blood cells in 1 } \mu\text{l of blood}}$$

**If:**

$$1 \text{ g} = 10^{12} \text{ pg}$$

$$1 \text{ ml} = 10^{3} \mu\text{l}$$

**Then:**

Weight (in pg) of hemoglobin in 1 μl of blood

$$= \frac{\text{Hemoglobin} \times 10^{12} \text{ pg}}{100 \times 10^{3} \mu\text{l}}$$

$$= \text{Hemoglobin} \times 10^{7} \text{ pg}/\mu\text{l}$$

**If:**

Hemoglobin = 15.0 g/dl
Red blood cell count = 5,000,000/μl

**Then:**

$$\text{MCH} = \frac{15 \times 10^{7} \text{ pg}/\mu\text{l}}{5 \times 10^{6} \mu\text{l}}$$

$$= \frac{15 \times 10 \text{ pg}}{5}$$

$$= 30 \text{ pg}$$

$$\text{MCH} = \frac{\text{Hemoglobin} \times 10}{\text{Red blood cell count in millions}} \text{ pg}$$

Normal value for the MCH: 27–31 pg

### DISCUSSION

The MCH indicates the amount of hemoglobin in the red blood cell and should always correlate with the MCV and MCHC. An MCH lower than 27 pg is found in microcytic anemia and also with normocytic, hypochromic red blood cells. An elevated MCH occurs in macrocytic anemias and in some cases of spherocytosis in which hyperchromia may be present.

## Mean Corpuscular Hemoglobin Concentration (MCHC)

The MCHC is an expression of the average concentration of hemoglobin in the red blood cells. It gives the ratio of the weight of hemoglobin to the volume of the red blood cell.

$$MCHC = \frac{\text{Hemoglobin in g/dl}}{\text{Hematocrit/dl}} \times 100 \text{ (to convert to \%)}$$

If:

Hemoglobin = 15.0 g/dl
Hematocrit = 45%

Then:

$$MCHC = \frac{15.0 \text{ g/dl} \times 100}{45 \text{ volumes/dl}} \% = 33\%$$

Therefore, the formula:

$$MCHC = \frac{\text{Hemoglobin} \times 100}{\text{Hematocrit}} \%$$

Normal value for the MCHC: 32–36%

### DISCUSSION

The MCHC indicates whether the red blood cells are normochromic, hypochromic, or hyperchromic. An MCHC below 32% indicates hypochromia, an MCHC above 36% indicates hyperchromia, and red blood cells with a normal MCHC are termed normochromic.

## Mean Corpuscular Volume (MCV)

The MCV indicates the average volume of the red blood cells.

$$\text{MCV} = \frac{\text{Volume of red blood cells in femtoliters (fl)}/\mu l \text{ of blood}}{\text{Red blood cells}/\mu l \text{ of blood}}$$

**If:**

Hematocrit = 45% (or 0.45)

Red blood cell count = $5{,}000{,}000/\mu l$ (or $5.0 \times 10^6/\mu l$)

$1\ \mu l = 10^9$ fl

**Then:**

$$\text{MCV} = \frac{0.45 \times 10^9\ \text{fl}/\mu l}{5.0 \times 10^6/\mu l}$$

$$= \frac{45 \times 10\ \text{fl}}{5}$$

$$= 90\ \text{fl}$$

**Therefore, the formula:**

$$\text{MCV} = \frac{\text{Hematocrit} \times 10}{\text{Red blood cell count in millions}}\ \text{fl}$$

Normal value for the MCV: 80–97 fl

### DISCUSSION

The MCV indicates whether the red blood cells appear normocytic, microcytic, or macrocytic. If the MCV is less than 80 fl, the red blood cells are microcytic. If the MCV is greater than 97 fl, the red blood cells are macrocytic. If the MCV is within the normal range, the red blood cells are normocytic.

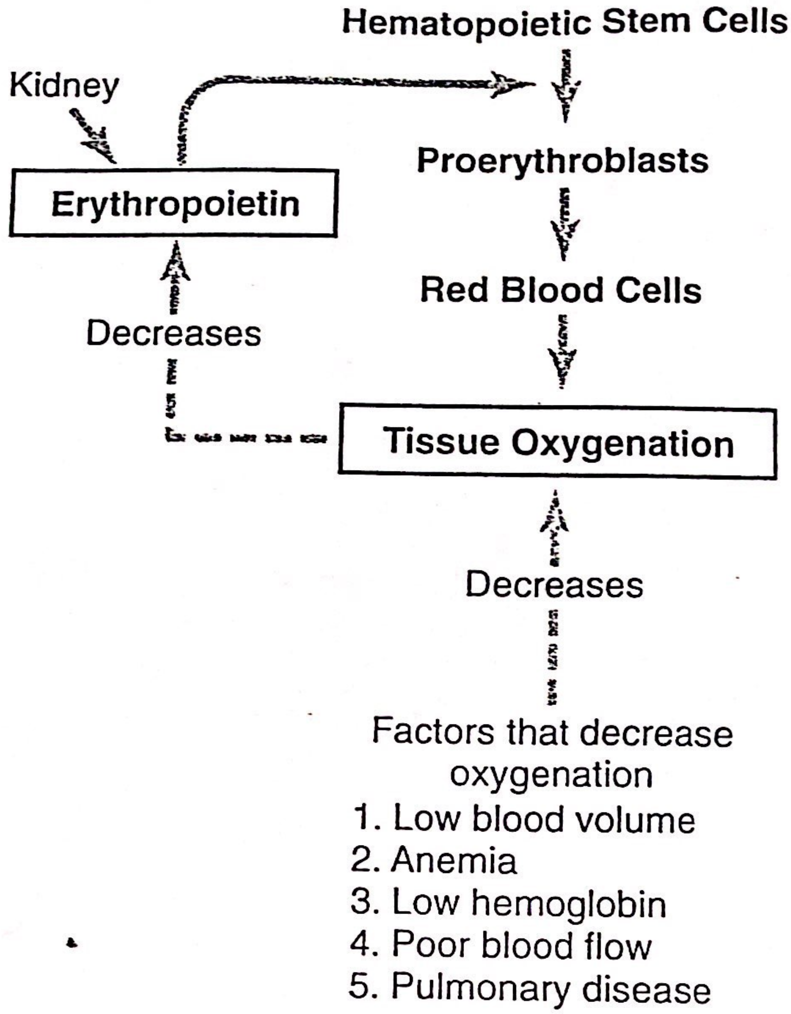



**Figure 32–4**

Function of the erythropoietin mechanism to increase production of red blood cells when tissue oxygenation decreases.

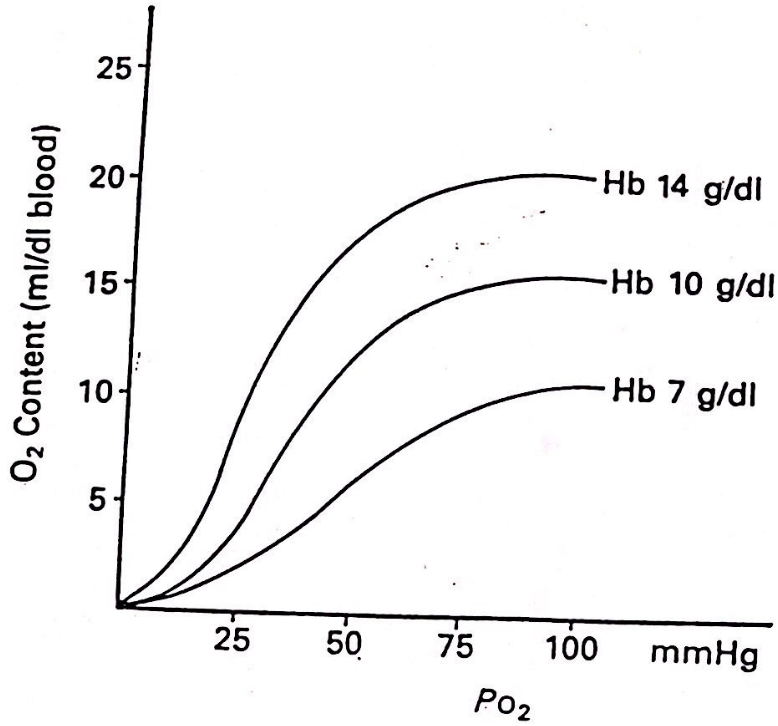
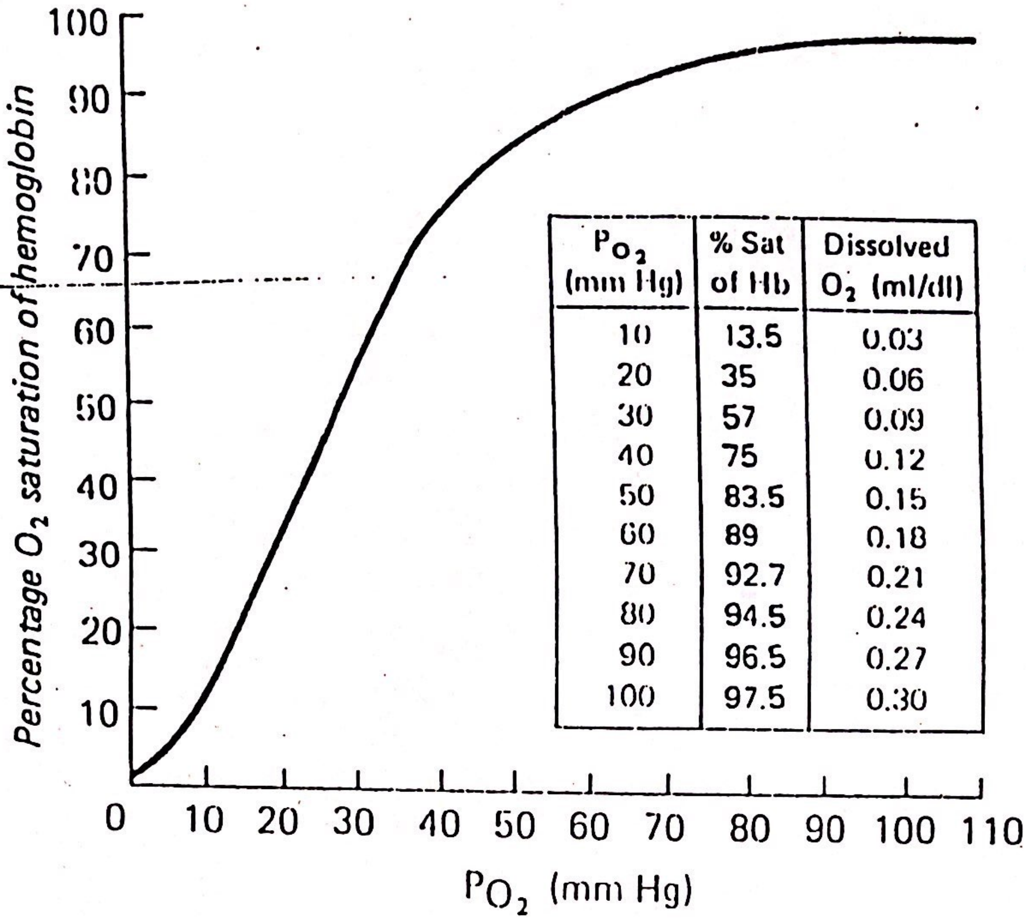



**Fig. 6.12** Effect of anaemia on oxygen content of the blood at different $Po_2$ values.

*It is evident that the quantity of oxygen carried in a volume of blood is dependent on the $Po_2$ as well as the haemoglobin concentration.*The percentage saturation of haemoglobin with oxygen is dependent on $Po_2$ and totally independent of haemoglobin concentration. If oxygen content (instead of percentage saturation of haemoglobin with oxygen) is plotted against $Po_2$, the level of the curve will be dependent on the haemoglobin concentration of the sample of blood (Fig. 6.12).*But when plotting percentage saturation against $Po_2$, as is usually done, the curve will always be the same, whatever the haemoglobin concentration is, if other factors remain the same.




| $P_{O_2}$ (mm Hg) | % Sat of Hb | Dissolved $O_2$ (ml/dl) |
|---|---|---|
| 10 | 13.5 | 0.03 |
| 20 | 35 | 0.06 |
| 30 | 57 | 0.09 |
| 40 | 75 | 0.12 |
| 50 | 83.5 | 0.15 |
| 60 | 89 | 0.18 |
| 70 | 92.7 | 0.21 |
| 80 | 94.5 | 0.24 |
| 90 | 96.5 | 0.27 |
| 100 | 97.5 | 0.30 |

**Figure 35–2.** Oxygen-hemoglobin dissociation curve. pH 7.40, temperature 38°C. (Redrawn and reproduced, with permission, from Comroe JH Jr et al: *The Lung: Clinical Physiology and Pulmonary Function Tests,* 2nd ed. Year Book, 1962.)

$$Hb_4 + O_2 \rightleftarrows Hb_4O_2$$
$$Hb_4O_2 + O_2 \rightleftarrows Hb_4O_4$$
$$Hb_4O_4 + O_2 \rightleftarrows Hb_4O_6$$
$$Hb_4O_6 + O_2 \rightleftarrows Hb_4O_8$$

Combination of the first heme in the Hb molecule with $O_2$ increases the affinity of the second heme for $O_2$, and oxygenation of the second increases the affinity of the third, etc, so that the affinity of Hb for the fourth $O_2$ molecule is many times that for the first.

Scanned with CamScanner

*Table 27–5.* Characteristics of human red cells.[1]

| | | Male | Female |
|---|---|---|---|
| Hematocrit (Hct)(%) | | 47 | 42 |
| Red blood cells (RBC) ($10^6/\mu L$) | | 5.4 | 4.8 |
| Hemoglobin (Hb) (g/dL) | | 16 | 14 |
| Mean corpuscular volume (MCV) (fL) | $= \frac{Hct \times 10}{RBC\ (10^6/\mu L)}$ | 87 | 87 |
| Mean corpuscular hemoglobin (MCH) (pg) | $= \frac{Hb \times 10}{RBC\ (10^6/\mu L)}$ | 29 | 29 |
| Mean corpuscular hemoglobin concentration (MCHC) (g/dL) | $= \frac{Hb \times 100}{Hct}$ | 34 | 34 |
| Mean cell diameter (MCD) (µm) | = Mean diameter of 500 cells in smear | 7.5 | 7.5 |

[1]Cells with MCVs > 95 fL are called macrocytes; cells with MCVs < 80 fL are called microcytes; cells with MCHs < 25 g/dL are called hypochromic.

*The red blood cell indices are used as an aid in differentiating anemias. When these indices are combined with an examination of the red blood cells on the stained smear, a clear picture of red blood cell morphology may be obtained.

with Corresponding Red Blood Cell Morphology

1. $MCV = \frac{41 \times 10}{4.5} = 91\ fl$

$MCH = \frac{14.0 \times 10}{4.5} = 31\ pg$

$MCHC = \frac{14.0 \times 100}{41} = 34\%$

The red blood cells are normocytic and normochromic.

2. $MCV = \frac{30 \times 10}{4.5} = 67\ fl$

$MCH = \frac{9.8 \times 10}{4.5} = 22\ pg$

$MCHC = \frac{9.8 \times 100}{30} = 33\%$

The red blood cells are microcytic and normochromic.

3. $MCV = \frac{30 \times 10}{4.5} = 67\ fl$

$MCH = \frac{9.0 \times 10}{4.5} = 20\ pg$

$MCHC = \frac{9.0 \times 100}{30} = 30\%$

The red blood cells are microcytic and hypochromic.

4. $MCV = \frac{45 \times 10}{4.0} = 113\ fl$

$MCH = \frac{15.0 \times 10}{4.0} = 38\ pg$

$MCHC = \frac{15.0 \times 100}{45} = 33\%$

The red blood cells are macrocytic and normochromic.

5. $MCV = \frac{41 \times 10}{4.5} = 91\ fl$

$MCH = \frac{11.8 \times 10}{4.5} = 26\ pg$

$MCHC = \frac{11.8 \times 100}{41} = 29\%$

The red blood cells are normocytic and hypochromic.

1. Iron deficiency is estimated to affect about 30% of the world population.
2. Iron deficiency Anemia is still the most important deficiency related to malnutrition.
3. Iron deficiency anemia (IDA) and thalassemia trait (TT) are the most common forms of microcytic anemia.
4. Some discrimination indices calculated from red blood cell indices are defined and used for rapid discrimination between TT and IDA.
5. Iron-deficiency anemia (IDA) is a common clinical problem throughout the world and an enormous public health risk in developing and even in industrialized countries.
6. Traditionally, several methods other than serum ferritin were used to assess IDA.

## Functions of Red Blood Corpuscles :

**(1) ... The main function of the red blood corpuscles is to carry oxygen to & take up carbon dioxide from the tissues.**

**<u>The biconcave shape of the cells is best suited for this function as it provides maximum surface for diffusion of gases for the volume of the corpuscles.</u>**
**(fig. 7).**

**(2) ... Hemoglobin in the red blood corpuscles is an important buffer & helps to keep the pH of blood constant.**

**(3) ... The red corpuscles keep hemoglobin inside them & prevent its loss in the urine.**

**(4) ... If the hemoglobin was free in the plasma, this would lead to :**

**([illegible]) ... The viscosity of blood will be increased → increase the work done by the heart to pump the blood in blood vessels.**

*** <u>Thus the red blood corpuscles by keeping hemoglobin inside them decrease the work performed by the heart.</u>**

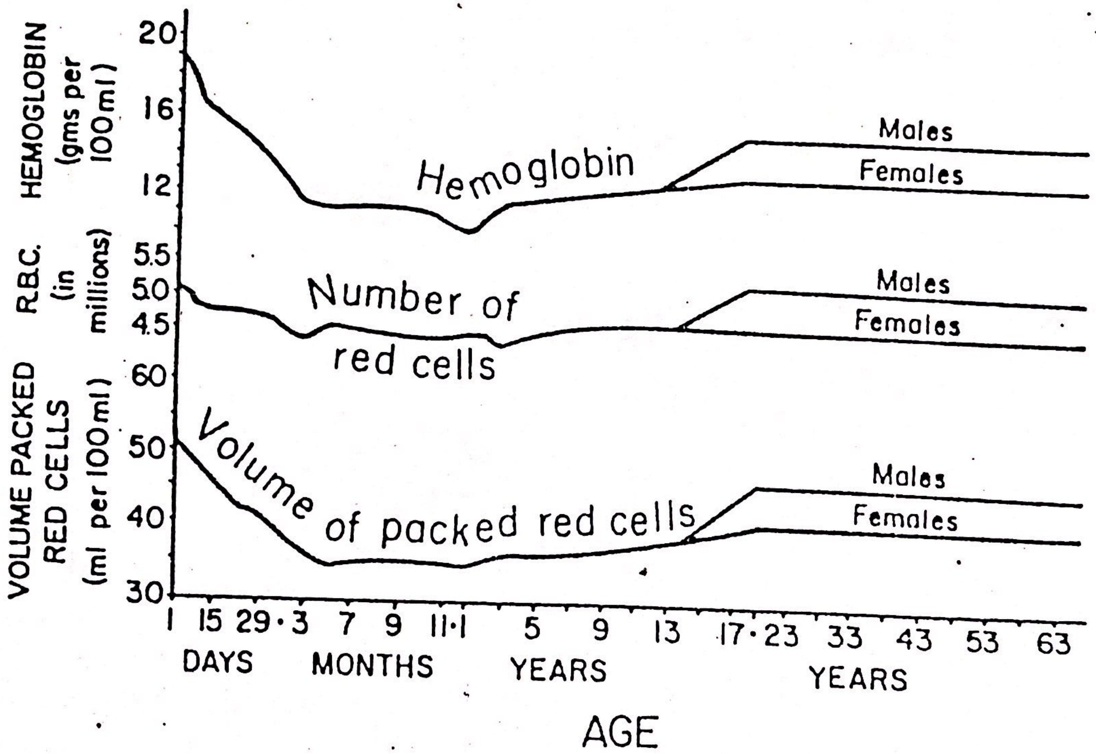
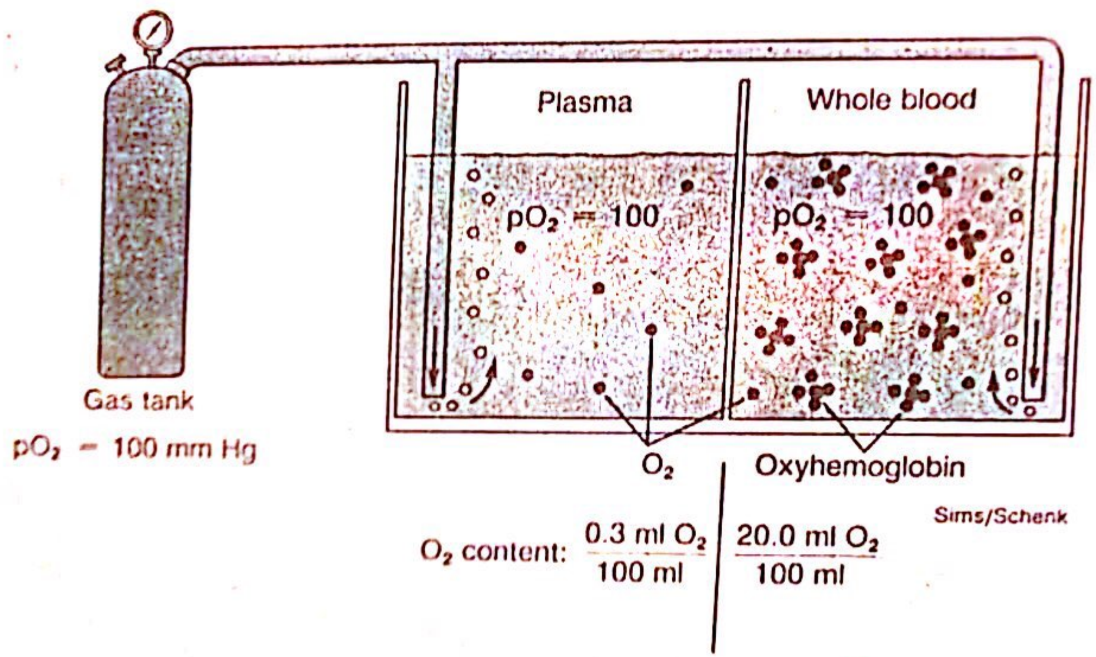



**Figure 4–1.** Relationship of age and sex to the hemoglobin content, red blood cell count and hem...




1 gr. Hb → 1.34 ml $O_2$

Heme is also part of the structure of **myoglobin,** an oxygen-binding pigment found in red (slow) muscles. In addition, **neuroglobin,** an oxygen-binding globin, is found in the brain.

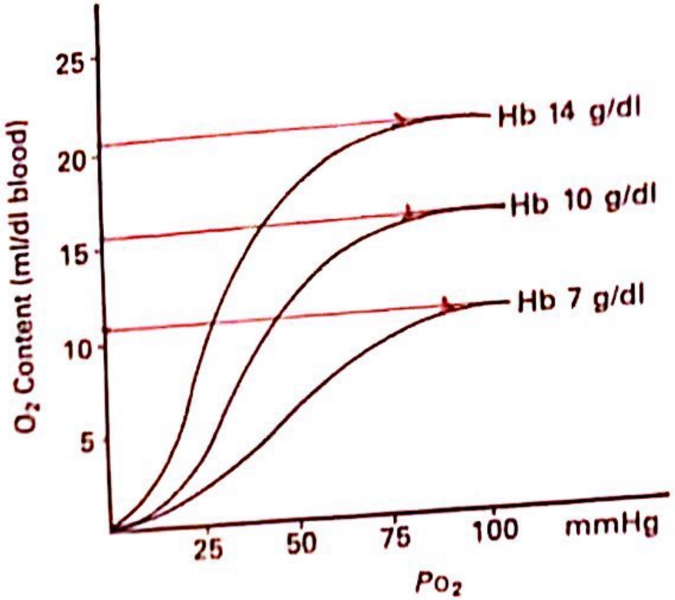



**Fig. 6.12** Effect of anaemia on oxygen content of the blood at different $Po_2$ values.

... quantity of oxygen carried in a

$Po_2$

**Fig. 6.12** Effect of anaemia on oxygen content of the blood at different $Po_2$ values.

It is evident that the **quantity** of oxygen carried in a volume of blood is dependent on the $Po_2$ as well as the haemoglobin concentration. The percentage saturation of haemoglobin with oxygen is dependent on $Po_2$ and totally independent of **haemoglobin concentration**. If oxygen content (instead of percentage saturation of haemoglobin with oxygen) is plotted against $Po_2$, the level of the curve will be dependent on the haemoglobin concentration of the sample of blood (Fig. 6.12). But when plotting **percentage saturation** against $Po_2$, as is usually done, the curve will always be the same, whatever the haemoglobin concentration is, if other factors remain the same.

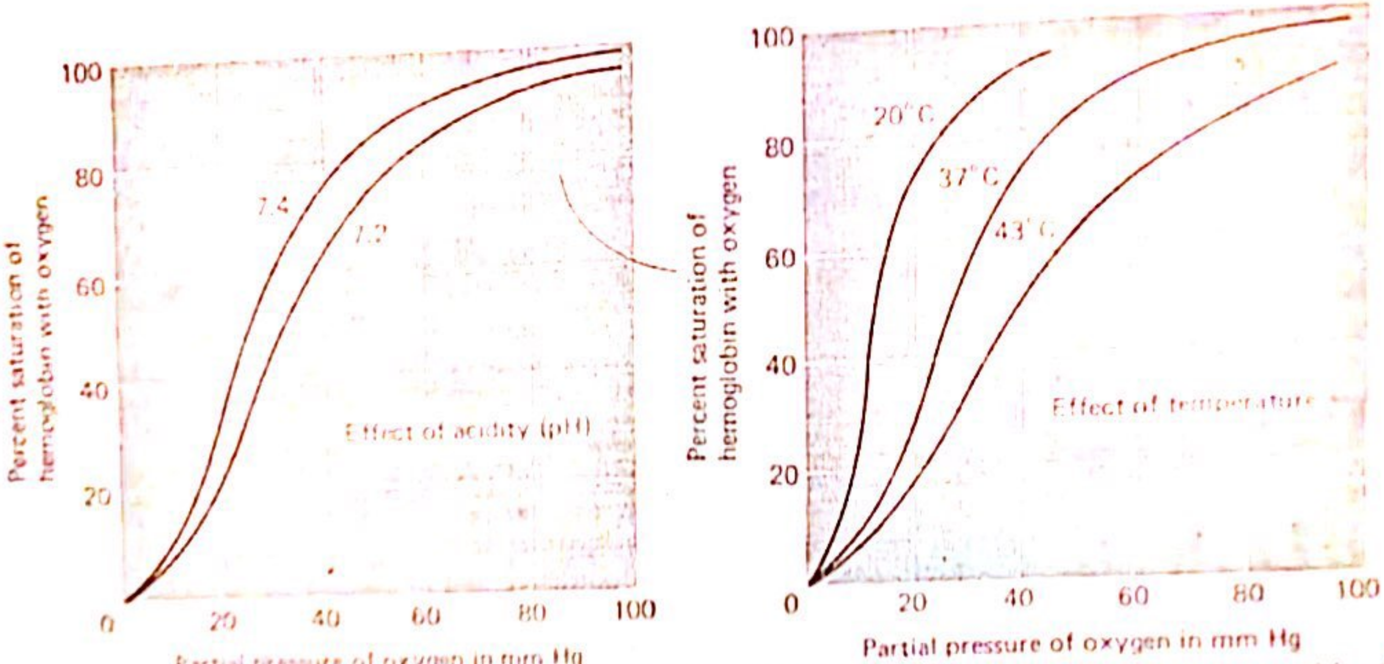



**Figure 17.16 Effects of Acidity and Temperature on Oxygen Dissociation from Hemoglobin.** As the blood becomes more acidic or as its temperature rises, the dissociation curve shifts to the right (color). For example, the curve shifts rightward as contracting muscles add carbonic acid, lactic acid, and heat to the blood during strenuous exercise. These additions—as shown by comparison of the old and new curves—cause more oxygen than usual to be released from hemoglobin. (Modified and reproduced with permission from J. H. Comroe, Jr., *Physiology of Respiration*, 2d ed., p. 185. Copyright © 1974 by Year Book Medical

**Table 2.2.** Classification of anaemias

| *Morphological* | *MCHC (%)* | *MCV (fl)* |
|---|---|---|
| 1. Normochromic normocytic | 32–36 | 76–96 |
| 2. Hypochromic normocytic | 32 | 76–96 |
| 3. Hypochromic microcytic | < 32 | < 76 |
| 4. Macrocytic | Usually normal | > 96 |
| 5. Microspherocytic | Usually normal | Normal but diameter reduced |

| *Aetiological* | |
|---|---|
| 1. Increased blood loss | |
| (*a*) Haemorrhage | (i) Acute<br>(ii) Chronic |
| (*b*) Haemolysis | (i) Corpuscular defects<br>(ii) Extracorpuscular defects |
| 2. Decreased blood production | |
| (*a*) Nutritional deficiency | (i) Iron<br>(ii) Folic acid, cobalamin<br>(iii) Pyridoxine<br>(iv) Ascorbic acid<br>(v) Protein |
| (*b*) Bone marrow failure | (i) Primary (idiopathic)<br>(ii) Secondary to drugs, chemicals, irradiation<br>(iii) Other |

EFFECTS OF ANEMIA ON THE CIRCULATORY SYSTEM

1. In severe anemia the blood viscosity may fall to as low as 1.5 times that of water rather than the normal value of approximately 3 times the viscosity of water.

2. The greatly decreased viscosity decreases the resistance to blood flow in the peripheral vessels so that far greater than normal quantities of blood return to the heart.

3. Moreover, hypoxia due to diminished transport of oxygen by the blood causes the tissue vessels to dilate, allowing further increase in the return of blood to the heart, increasing the cardiac output to a still higher level.

4. Thus, one of the major effects of anemia is greatly increased work load on the heart.

5. Consequently, during exercise, which greatly increases the tissue demand for oxygen, extreme tissue hypoxia results, and acute cardiac failure often ensues.

# Classification of erythrocytosis

I. *Relative erythrocytosis*
Dehydration

II. *True erythrocytosis*
A. *With increased* EP level.
1 Physiological– high altitude (Hypoxia)
2. Drugs
(a) Cobalt
(b) Androgens, thyroxine
B. *With low or normal* EP. level
= Polycythaemia vera

EFFECT OF POLYCYTHEMIA ON THE CIRCULATORY SYSTEM.

1. The greatly increased viscosity of the blood in polycythemia, this increases the heart work.

2. The flow of blood through the vessels is often very sluggish.

3. It is obvious that increasing the viscosity tends to decrease the rate of venous return to the heart.

4. On the other hand, the blood volume is greatly increased in polycythemia, which tends to increase the venous return.

5. The blood passes sluggishly through the skin capillaries, a larger than normal proportion of the hemoglobin is deoxygenated. The blue colour of this deoxygenated hemoglobin masks the red color of the oxygenated hemoglobin. Therefore, a person with polycythemia ordinarily has a ruddy complexion but often with a bluish (cyanotic) tint to the skin.