ncluded in the list.
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).59	1,2
5.94	3,4,6
4.24	3
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7.0482	4,5,6
3.69	2,3
2.9064	3,5
1.0067	3,5
259)	. . .
).2	2,3,4,8
5.9994	2
5.42	2,4,6
).9738	3,5
5.08	2,4
244)	3,4,5,6
209)	. . .
).0983	1
).908	3
145)	3
.0359	. . .
5.025	2
222)	0
5.207	. . .
2.906	3
.4678	1
.07	3,4,6,8
.36	2,3
.9559	3
.96	2,4,6
.0855	4
.868	1
.9898	1
.62	2
.06	2,4,6
.9479	5
98)	6,7
.60	2,4,6
.925	3
.383	1,3
.038	4
.934	3
.71	2,4
.88	3,4
.85	6
.029	4,6
.9415	3,5
.29	0
.04	2,3
.9059	3
.39	2
.224	4

try and Physics,

a LANGE medical book

Review of Medical Physiology

seventeenth edition

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Norwalk, Connecticut

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Section VII. Respiration

Pulmonary Function 34

INTRODUCTION

Respiration, as the term is generally used, includes 2 processes: **external respiration,** the absorption of O_2 and removal of CO_2 from the body as a whole; and **internal respiration,** the utilization of O_2 and production of CO_2 by cells and the gaseous exchanges between the cells and their fluid medium. Details of the utilization of O_2 and the production of CO_2 by cells are considered in Chapter 17. This chapter is concerned with the functions of the respiratory system in external respiration, ie, the processes responsible for the uptake of O_2 and excretion of CO_2 in the lungs. Chapter 35 is concerned with the transport of O_2 and CO_2 to and from the tissues.

The respiratory system is made up of a gas-exchanging organ (the lungs) and a pump that ventilates the lungs. The pump consists of the chest wall; the respiratory muscles, which increase and decrease the size of the thoracic cavity; the areas in the brain that control the muscles; and the tracts and nerves that connect the brain to the muscles. At rest, a normal human breathes 12–15 times a minute. Five hundred milliliters of air per breath, or 6–8 L/min, is inspired and expired. This air mixes with the gas in the alveoli, and, by simple diffusion, O_2 enters the blood in the pulmonary capillaries while CO_2 enters the alveoli. In this manner, 250 mL of O_2 enters the body per minute and 200 mL of CO_2 is excreted.

Traces of other gases such as methane from the intestines are also found in expired air. Alcohol and acetone are expired when present in appreciable quantities in the body. Indeed, over 250 different volatile substances have been identified in human breath.

PROPERTIES OF GASES

Partial Pressures

Unlike liquids, gases expand to fill the volume available to them, and the volume occupied by a given number of gas molecules at a given temperature and pressure is (ideally) the same regardless of the composition of the gas.

$$P = \frac{nRT}{V} \quad \text{(from equation of state of ideal gas)}$$

where

P = Pressure
n = Number of moles
R = Gas constant
T = Absolute temperature
V = Volume

Therefore, the pressure exerted by any one gas in a mixture of gases (its **partial pressure**) is equal to the total pressure times the fraction of the total amount of gas it represents.

The composition of dry air is 20.98% O_2, 0.04% CO_2, 78.06% N_2, and 0.92% other inert constituents such as argon and helium. The barometric pressure (P_B) at sea level is 760 mm Hg (one atmosphere). The partial pressure (indicated by the symbol P) of O_2 in dry air is therefore 0.21 × 760, or 160 mm Hg at sea level. The partial pressure of N_2 and the other inert gases is 0.79 × 760, or 600 mm Hg; and the P_{CO_2} is 0.0004 × 760, or 0.3 mm Hg. The water vapor in the air in most climates reduces these percentages, and therefore the partial pressures, to a slight degree. Air equilibrated with water is saturated with water vapor, and inspired air is saturated by the time it reaches the lungs. The P_{H_2O} at body temperature (37 °C) is 47 mm Hg. Therefore, the partial pressures at sea level of the other gases in the air reaching the lungs are P_{O_2}, 149 mm Hg; P_{CO_2}, 0.3 mm Hg; and P_{N_2} (including the other inert gases), 564 mm Hg.

Gas diffuses from areas of high pressure to areas of low pressure, the rate of diffusion depending upon the concentration gradient and the nature of the barrier between the 2 areas. When a mixture of gases is in contact with and permitted to equilibrate with a liquid, each gas in the mixture dissolves in the liquid to an extent determined by its partial pressure and its

Table 34–1. Standard conditions to which measurements involving gas volumes are corrected.

STPD	0 °C, 760 mm Hg, dry (standard temperature and pressure, dry)
BTPS	Body temperature and pressure, saturated with water vapor
ATPD	Ambient temperature and pressure, dry
ATPS	Ambient temperature and pressure, saturated with water vapor

solubility in the fluid. The partial pressure of a gas in a liquid is that pressure which in the gaseous phase in equilibrium with the liquid would produce the concentration of gas molecules found in the liquid.

Methods of Quantitating Respiratory Phenomena

Respiratory excursions can be recorded by devices that measure chest expansion, or by recording spirometers (see Fig 17–1), which also permit measurement of gas intake and output. Since gas volumes vary with temperature and pressure and since the amount of water vapor in them varies, it is important to correct respiratory measurements involving volume to a stated set of standard conditions. The 4 most commonly used standards and their abbreviations are shown in Table 34–1. Modern techniques for gas analysis make possible rapid, reliable measurements of the composition of gas mixtures and the gas content of body fluids. For example, O_2 and CO_2 electrodes, small probes sensitive to O_2 or CO_2, can be inserted into the airway or into blood vessels or tissues and the P_{O_2} and P_{CO_2} recorded continuously. Chronic assessment of oxygenation is carried out noninvasively with a **pulse oximeter,** which is usually attached to the ear. Absorption of light passing through tissue is mathematically related to the amount of oxyhemoglobin in the tissue, and the pulse oximeter eliminates the constant absorption due to tissue and other components and measures only the absorption of pulsatile arterial blood. CO_2, carbon monoxide (CO), and many anesthetic gases can be measured rapidly by infrared absorption spectroscopy. Gases can also be measured by gas chromatography or mass spectrometry.

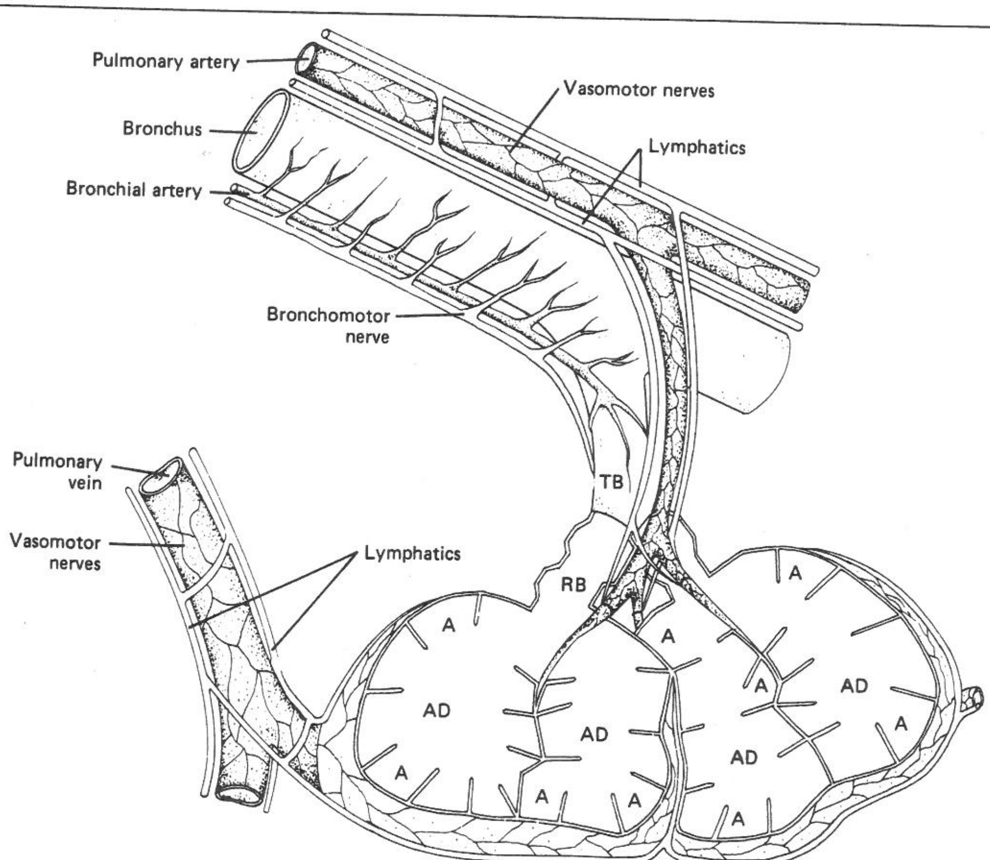

Figure 34–1. Structure of the lung. A, alveolus; AD, alveolar duct; RB, respiratory bronchiole; TB, terminal bronchiole. (Reproduced, with permission, from Staub NC: The pathophysiology of pulmonary edema. *Hum Pathol* 1970;**1:**419.)