seventeenth century that advances in diving technique were made rapidly. The advances made in that century served to recover the riches sunk with the Spanish Armada.[3] It was another century before pumps were used to supply air to divers, and it was with this means of prolonging diving time that intimations of physiological factors began to appear in the scientific writings. It was no longer a matter of "fresh air" but the realization that compression and more especially decompression were hazardous and required deliberate and slow schedules for the attainment of gaseous equilibrium between the body and its environment. A logical basis for decompression was not discovered until Paul Bert[1,2,4] did his fundamental work on the effects of atmospheric pressure on the body.

The effects of rarefied atmospheres were known in ancient times, but the only significant deductions were concerned with their geographic distribution. Thus, the inhabitants of Alpine, Himalayan, and Andean regions were known to be industrious and healthy people casually undifferentiable from the lowlanders, yet the latter in travels through these regions collapsed or at least were ill and incapable of exertion. However Acosta, in 1590,[1,2] wrote that in trans-Andean trips even the natives were affected by extreme altitude, and he rightly concluded that the "fine and thin air" was unsuited to the requirements of respiration.

It was not until abrupt ascent into the atmosphere became feasible that the pioneer balloonists found—by bitter experience—the necessity for detailed knowledge of the effects of lowered atmospheric pressure on the body. It was again the researches of Paul Bert[4] from 1871 to 1883, spurred on by the tragic outcome of ascents of Sivel, Croce-Spinelli, and Tissandier (1875), that started the analysis of these effects and laid a rational groundwork for the entire field.

In essence, the problems in physiology presented by abnormal atmospheric pressure deal with the vagaries of the physical solution of gases in the body fluids, the pressure-labile chemical changes of oxygen and carbon dioxide in the body, and the concomitant effects of these factors on the complex systems of adjustment that the mammalian organism, in particular, has evolved.

Because of certain differences, in various factors, that exist between the two types of abnormal pressure, increased and reduced pressure will each be considered separately and then followed by a discussion of the common properties. In order to understand the intimate difficulties encountered by the body in each of the two ranges of pressure it is necessary to recapitulate the properties of gases of the atmosphere, first, with respect to each other and their geographical distribution and, second, with respect to their individual characters. (For a detailed treatment of the subject see the excellent work of Humphreys.[5])

[3] Meyer, *Conversations Lexicon.* 5th ed., Bibliographisches Institute, Leipzig and Vienna, 1893.

[4] P. Bert, *La pression barométrique.* Available in English as *Barometric Pressure.* Trans. by M. A. and F. A. Hitchcock. College Book Co., Columbus, Ohio, 1943.

[5] W. J. Humphreys, *Physics of the Air.* 3rd ed., McGraw-Hill, New York, 1940.

II. Properties of the Atmosphere

A. COMPOSITION

The composition of the atmosphere near the earth's surface is given in Chapter VI (page 143), and therefore the components will not be tabulated here.

With the exception of carbon dioxide and ozone, the gases normally present in the air are distributed in relatively unvarying percentages from the level of depressions (—1292 feet in the Dead Sea Basin) to an altitude of about 65,000 feet. Above this altitude there is no thermal mixing of the atmosphere and there is evidence that a progressive decrease in the concentration of the heavier gases occurs as a result of gravitational separation. This level is above the altitude at which, on theoretical grounds, the boiling point of water in the body would be attained and far above the level at which pure oxygen will no longer suffice for supplying the metabolic needs. The composition of the atmosphere at these altitudes is mainly of engineering interest in the construction of stratosphere craft depending on ambient gases for pressurization of cabins.

The presence of such a variable constituent as ozone is accounted for by different theories. Besides local concentrations due to electrical discharges through the atmosphere there is a diffusion of ozone downward from extreme altitudes at which oxygen is thought to be converted to ozone by the absorption of energy from the sun.[6] Its instability prevents any accumulation to deleterious concentrations, as far as is known, in the vital altitude range given above.

Carbon dioxide is present in appreciable concentration only near the surface of the earth and may accumulate to a variable extent only in confined or circumscribed areas in which combustion of carbon or other release of carbon dioxide is taking place. In nature it may become a limiting factor for life, for example, in certain grottoes where various processes free carbon dioxide from the rock to accumulate in the air in high concentration.[7] Carbon dioxide is also encountered in dangerous concentration in caisson work, in mines, and in tunnels.[4]

In general, water vapor in the external air does not limit the use of the atmosphere for respiratory purposes, but as will be seen later, at high altitudes water vapor can physically displace other gases from the lungs. As far as can be ascertained, its concentration in air of caissons and tunnel heads produces no serious deleterious effects. In the external atmosphere it attains a very low value at the lower level of the isothermal layer[6] (stratosphere).

The only instances of significant concentrations of abnormal constituents and excessive concentrations of normal constituents are in situations similar to the above, that is, in confined or restricted areas. Conditions often are aggravated by the fact that these abnormal constituents form layers whose concentrations are inimical to life. In any case, the factor of natural positive atmospheric pressure is of importance only because chemical reactions in metabolic systems

[6] S. Ruff and H. Strughold, *Grundrisse der Flugfahrtmedizin.* Barth, Leipzig, 1939.

[7] E. L. Quinn and C. L. Jones, *Carbon Dioxide.* Reinhold, New York, 1936.