argon, and krypton, is usually thought to be purely physical. Certainly under vital conditions in mammals there is no corroborated evidence that nitrogen gas can enter into chemical reactions.[24] On the other hand, observations at high positive pressures, by Behnke and Yarbrough[35] and others, have led to the postulation of a quasi-physical or chemical action that may be involved in the production of a "narcosis" under these conditions by nitrogen and argon and not by the lighter gases such as helium and hydrogen.[36] There does not seem to be present any known cause for these effects except that the behavior of gases does not follow the usual relations when high pressures exist. Recently similar observations have been made at atmospheric pressure with xenon and argon[37] and helium and argon[38,39] in both man and lower animals.

III. Effects of Increased Atmospheric Pressure on the Body

A. CHARGING OF THE BODY WITH GASES

1. Mechanical Effects

Mechanical effects of compression of the environmental gases on the fluid and solid constituents of the living system are negligible because of the incompressibility of these constituents. On the other hand, since pressure is transmitted undiminished throughout these substances of the body, displacement of fluid or tissue into any gas space not continuous with the atmosphere is unavoidable. Such gas spaces are, unfortunately for those concerned, present in the body, particularly in the middle ear and various sinuses in the head; of lesser importance are the included abdominal and other gases.

In general the mechanical effects in natural diving are only quantitatively different from those in caisson diving, while suit diving adds a mechanical hazard called "the squeeze," which is really a macroscopic extension of the above principle, in that here the body is forced into the helmet if air pressure fails to balance water pressure. It is of considerable practical importance because collapse of the lungs with massive congestive hemorrhage results quite early in such cases.

The middle ear, including the mastoid sinus, has only intermittent connection with the external atmosphere through the soft-walled eustachian tube. On compression the eardrum and this pharyngeal structure, which is normally collapsed up to the point where it is enclosed in the bony structure of the head and thus forms a stopper, are pushed progressively inward. If voluntary opening of this tube is not affected by movement of the adjacent muscles during swallowing, then continued increase in pressure causes a displacement of the eardrum into the lumen of the middle ear with varying degrees of trauma, and, more importantly,

[35] A. R. Behnke and O. D. Yarbrough, *U. S. Naval Med. Bull.*, **36**, 549 (1938).
[36] E. M. Case and J. B. S. Haldane, *J. Hyg.*, **41**, 225 (1941).
[37] J. H. Lawrence *et al.*, *J. Physiol.*, **105**, 197 (1946).
[38] S. F. Cook, *J. Cellular Comp. Physiol.*, **36**, 115 (1950).
[39] S. F. Cook *et al.*, *Am. J. Physiol.*, **164**, 248 (1951).

displacement of blood into the capillary lining of this cavity, resulting in ...ent reddening, petechial and massive hemorrhage, and occasionally rupture ...the tympanum.[40] In addition, there is an early dulling of the hearing, which is ...due to the marked displacement of the incus, malleus, and stapes, preventing ...them from transmitting sound vibrations to the middle ear properly. According ...to the experience of the Royal Navy[41] it is found that some degree of acute drum ...trauma is produced in all but the most experienced pressure workers.

The action of increased atmospheric pressure on the various sinuses is only deleterious and painful when, as in the ear, the openings are not patent. In normal individuals this is rare, but it is a chronic condition with some individuals, generally associated with infection or malformations. Obviously, acute infection of the upper respiratory tract tends to produce this condition. When the openings of the sinuses are thus occluded, an increase in atmospheric pressure will result in severe pain and varying degrees of trauma even with moderate pressure differences. This seeming disproportionality between cause and effect is due possibly to the rather large surface-to-volume ratio of most sinuses, allowing ready distension of large areas of capillaries. This distention leads to marked stimulation of deep pain receptors, with the observed sequelae of nausea, etc., due to autonomic discharge from this stimulation. As far as can be determined, reports from the older literature of mechanical trauma to the vascular system are to be attributed more to the various conditions enumerated above than to other gross hydraulic effects, as was formerly held.[42] It is true, however, that the blood ...forced into the capillaries lining any such rigid-walled, isolated gas space and, ...depending on the tonic state, may result in hemorrhage. If we assume a normal capillary pressure of 40 mm. Hg, it takes only $^1/_{19}$ atm. of positive pressure to double this value in the capillary bed of the ear or sinus. Clinical tests of capillary fragility are based on petechial hemorrhages in normal tissue with 50 mm. Hg pressure above normal![25]

Gases in the alimentary tract are, wherever located, subject to compression by body tissues and for the most part do not cause any inconvenience beyond the displacement of the viscera, which in most cases can be of only a benign nature. As will be shown subsequently, this does not absolve these gas entities from consideration since, unless passed as flatus, they expand on decompression.

There remains one more mechanical effect of compression that, while rare, is real and may produce drastic sequelae: this concerns the compression of the gases in the lungs. Offhand, no effect would be expected since almost continuous patency of the breathing passages is assumed. It must be recognized, however, that during rapid compression, closure of the glottis in swallowing or breath

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... *Roy. Naval Med. Bull.* No. 5, 13 (1943). Abst. in *Bull. War Med.*, **4**, 305 (1944).
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