WITH COMPLIMENTS OF THE AUTHOR.

ON THE CAUSES OF

CARDIAC FAILURE IN HIGH ALTITUDES.

BY

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ON THE CAUSES OF CARDIAC FAILURE IN HIGH ALTITUDES.

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Mr. President and Gentlemen—The extreme importance of this fact, that there is so often, not only in the weak and diseased but also in the strong and healthy, great dyspnœa and sudden cardiac failure in high altitudes, has not, I venture to assert, been sufficiently emphasized. It is not too broad a statement that many persons are sent for general or special reasons to high altitudes, who are done thereby permanent injury—especially may this be the case with those who are suffiering with any form of functional or organic heart disease. That such a procedure was or might be dangerous was forcibly impressed upon me in the course of some experiments (with the pneumatic cabinet) for the effect of rarified and compressed air upon the heart and circulation; and upon purely scientific grounds I declared in this Society a year ago that, before deciding a person to be a proper subject for treatment by rarefied or compressed air, *thorough examination* should be made of the *heart; and that no person found to have insufficiency or stenosis of the mitral or aortic valve, or the slightest tricuspid regurgitation, or a fatty or weak heart, should, under any condition, be subjected to treatment by rarefied and compressed air.*

You doubtless remember a paper by Prof. Loomis, read at our last meeting, "on the effects of high altitudes on cardiac diseases," in which he gave the history of six (he had then recorded twenty-two) cases of cardiac failure directly due to removal to a high altitude. In this paper Dr. Loomis says: "In these cases which I have quoted, as well as similar ones which have come under my observation, *the ventricular dilatation*, which was unquestionably the cause of the sudden development of the distressing symptoms, and from which dated the commencement of the fatal issue, seemed to be directly due to the effects on the *cardiac circulation of the change from a low to a high altitude.* I do not maintain that sudden cardiac dilatation might not have developed in any one of these cases under other conditions, but I do maintain that change in atmospheric pressure is a very important cause of sudden ventricular dilatation when any degree of heart insufficiency preëxists."

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Finally, he declares that only with danger can a person whose heart is weak, fatty or diseased, pass rapidly from a low to a high altitude; and, indeed, I gathered from his subsequent remarks that a person with cardiac disease should under no circumstances be sent to high altitudes.

Dr. Loomis, then, had arrived at the same conclusion from clinical experience as the author had experimentally; and it seems that we may rest assured that there is great danger for the diseased heart either in high altitudes or in any form of treatment by rarefied and compressed air. We are also supported in this conclusion by Dr. Solly of Colorado Springs. In a conversation with the writer Dr. Solly bore with great emphasis on the extreme danger to the weak or diseased heart of a sudden or even gradual removal to high altitudes, and that he was convinced from many years' experience at Colorado Springs that it was a precaution almost entirely neglected by the *average* practitioner.

The fact, then, would seen to admit of no doubt, both for scientific and clinical reasons. What then is the cause of this cardiac failure? It is very generally asserted that the cause of cardiac failure in high altitudes, in rarefied air, is the *want of oxygen*. That the system needing more oxygen, more blood has to be sent through the lungs in a given time, thus increasing the work to be done by the heart, which often dilates under the sudden strain. This explanation, so generally found in the text-books, though applicable for very high altitudes, is at the same time based on a misconception.

First—The partial pressure of oxygen at normal atmospheric pressure is equal to 150 millimetres of mercury.

Second—So long as the partial pressure of this gas remains above twenty-five millimetres of mercury (one inch) the amount taken up by the blood will depend upon the amount of hæmoglobin in that liquid, and not on how much oxygen there is in the air.

Third—The partial pressure of oxygen even at so great a height as 10,000 feet would be 101 millimetres of mercury, at which the hæmoglobin could get all the oxygen necessary.

But, it may be urged, Paul Bert found an increased amount of hæmoglobin in the blood of animals in high altitudes, which would show a necessity on the part of nature for more oxygen. True, but this change takes place only after a very long time, probably not in

one generation. Again, it may be objected that in many of those very cases sent to high altitudes the blood is poor in hæmoglobin. Doubtless this is true, but it is not the sick only, by any means, who suffer from dyspnœa and cardiac failure in high altitudes.

How may this clinical fact be more satisfactorily explained? However much the phenomena of normal quiet respiration may be changed in a highly rarefied atmosphere, the chief and immediate cause of dyspnœa and cardiac failure may, I think, be traced to *the diminished pressure on the heart walls and their consequent dilatation.* This fact may be made plain as follows:

The external air presses against the interior of the lungs with a pressure equal to that exerted on the same area by a column of mercury 760 millimetres high; it distends them and pushes them against the inside of the chest walls, the heart and great blood-vessels and contents of the thorax. The pressure thus exerted is not equal to that of the external air, since some of the total air pressure on the inside of the lungs is used up in overcoming their elasticity (equal to six millimetres of mercury), and it is only the residue, equal to a column of mercury 754 millimetres high, which pushes the lungs against the heart and great vessels. The actual pressure, then, on the heart walls, normally, is equal to 754 millimetres of mercury.

How is this pressure changed at an altitude, say, of 10,000 feet? The total pressure of the air at that altitude would be equal to a column of mercury 501 millimetres high. The pressure, then, upon the lungs and whole body would be lessened. But, as the person is breathing the same air as that around him, the respiratory act would be unchanged. Prof. Martin and the author found that neither the frequency nor depth of the respiratory act were changed in an animal placed in a rarefied atmosphere. There would be (as, again, we found) a slight fall in blood pressure, which would be very temporary; for the circulation, being a system of closed tubes, is but little, if any, affected, and the pressure rises at once to the normal, owing to increased vasomotor action. There would be no increase of negative intrathoracic pressure. Finally, the only organ directly affected at moderate altitudes (of course, at very high altitudes, 12,000 to 18,000 feet, the dyspnœa from want of oxygen would be

felt), say, from 3,000 to 10,000 feet, would be the heart, and for this reason. As we have said, the pressure on the heart usually is equal to 754 millimetres of mercury. At an altitude of 10,000 feet, however, the general pressure being 501 millimetres, the pressure of the heart would be only 495 millimetres of mercury. Now the arterial pressure, and, therefore, the intracardiac pressure, would be the same as when the pressure on the heart walls was 754 millimetres. But one result could follow such conditions, and that would be a stretching and dilatation of the heart walls—especially of the right side—and this is precisely what is found in many of those who go into high altitudes for their health or for other reasons, and what we found in experiments upon animals. The heart, weak and diseased possibly beforehand, is unable to stand such strain as is put upon its dilated walls, and so we find its contractions weak, intermittent and irregular,—we have the murmurs, the syncope, the dyspnœa, which are often so marked in high altitudes.

Of course, the want of oxygen is a great cause of the dyspnœa in very high altitudes; but we are quite justified, on physiological grounds, in saying that at the altitudes to which persons are ordinarily sent—three, four, six, seven, or even ten thousand feet—the hæmoglobin can take up all the oxygen the system needs.

Finally, then, and speaking purely from an experimental standpoint, I hold that there is danger to the weak and diseased heart, not only in the use of such apparatus as the pneumatic cabinet, but also in high altitudes; in which conclusion I am supported by the clinical experience of Prof. Loomis, and of Dr. Solly, of Colorado Springs.

And in this connection I might say that those gentlemen who are interested in the pneumatic cabinet ought certainly to have called more—I do not know that they have called any—attention to the great danger attending its use in cardiac disease. I shall accomplish the object of this short paper if I shall excite the comment and discussion on this most important point from some of the distinguished diagosticians here present.