take place more slowly. The reaction resembles more nearly that seen during an attack of mountain sickness among mountaineers. In such men the heart beat is greatly accelerated during the attack. The aviator, it appears, must depend largely on his heart and his breathing for compensation to the fall in oxygen that he encounters as he ascends.

III. CARDIOVASCULAR OBSERVATIONS*

JAMES L. WHITNEY, M.D. (SAN FRANCISCO)
Major, M. R. C., U. S. Army
MINEOLA, L. I., N. Y.

It has long been known that persons with defective hearts tolerate very badly such altitudes as those of Denver, Phoenix and Mexico City. Many instances have been quoted of serious and even fatal attacks of cardiac dilatation, pulmonary edema, etc., occurring within a few days after the arrival at these places. This popular view has, however, received up to the present very little confirmation from scientific work. Marked alterations in respiration have indeed been described; and the effects on the chemistry of the blood and tissues in reference to transport of oxygen have been studied in great detail. Beyond suggestions, however, that certain changes in blood flow might occur as the result of high altitudes, little evidence has been at hand that the effect on circulation is of great importance; especially there has been entire lack of proof of marked circulatory strain, or of the possibility of such disasters to the heart as have been popularly described.

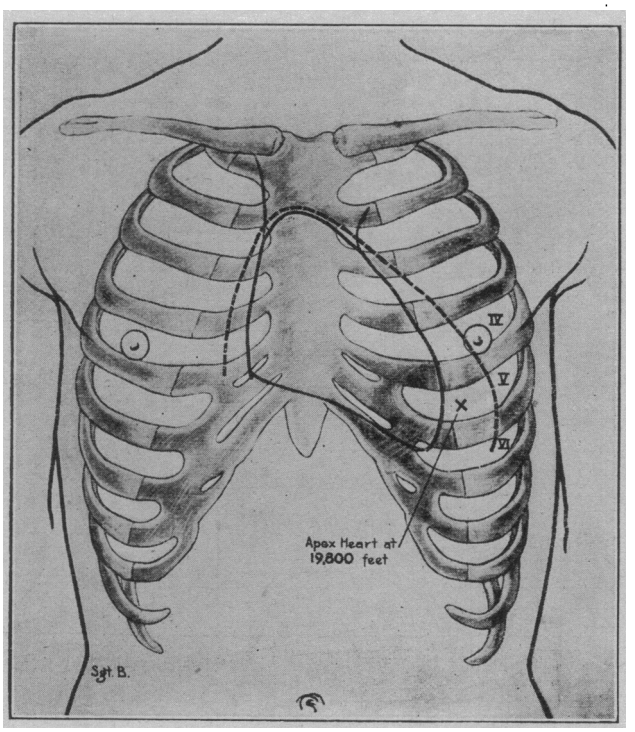

Fig. 1.—Dilatation of the heart under deficiency of oxygen beyond the individual's power of compensation: solid line, percussion outline of heart before and after experiment; broken line, outline at 19,800 feet elevation in low-pressure chamber.

The explanation is that the best type of organism makes its circulatory adjustments so smoothly and with so little strain that there is almost no evidence of anything of great importance going on. It is only by study of less normal types that we appreciate both the serious effects that may be due to failure of circulatory reaction, and the nature of this reaction itself.

Perhaps the most striking single fact brought to light by the present research is that heart failure following marked dilatation is exceedingly common as the result of reduction of atmospheric pressure. Dilatations of from 3 to 5 cm. have been not infrequently found, always followed by collapse and fainting if oxygen is not immediately given. The commonness of this syndrome may be judged from the experience of ten medical officers taken into the low-pressure chamber on two occasions for demonstration purposes. These were men of average constitution, though not of athletic type. Five of them developed marked dilatation, one at 14,000, one at 16,000, two at 18,000 and one at 20,000 feet. It was interesting that in each case the dilatation was discovered by percussion before any subjective symptom was present; but in each case the individual began to feel very ill within a minute thereafter and would have fainted if oxygen had not been administered. It is our practice in using the low-pressure chamber for the observer to take oxygen even at the lower "altitudes."

COMPENSATION BY THE CIRCULATORY SYSTEM FOR LOW OXYGEN

The explanation of many physiologic events lies in the power of the organism to make readjustments to compensate for deleterious changes in the environment. In the compensation for low oxygen, the circulation appears to be the factor of first importance. Changes in respiration, in concentration or chemical constitution of the blood, or in the mechanism of gaseous exchange are important, but they are able to make good only partially for the deficiency. The factor of chief importance with a wide range of adaptability is the rate of blood flow, both in general and as regards special parts. If the blood carries less oxygen per unit, more blood must be sent to the organs that need it in order to furnish the sum total of the amount that is required.

This, of course, means increase in pulse rate, often increase of blood pressure (especially of pulse pressure) and delicate readjustments of blood distribution. All of this calls for accurate control of the vasomotor system and increased strain on the heart. This strain must be carried at a time when the oxygen supply of the heart muscle itself is precarious.

Not only is the maintenance of perfect circulation vitally important for efficient existence at high altitudes, but the heart is itself particularly vulnerable to direct effects of oxygen deficiency. There is the possibility of a vicious circle of a most dangerous kind. For if the circulation falters for a moment, not only will the nerve centers run the risk of subjection to a paralyzing anoxemia, but the nutrition of the heart muscle is impaired. Further interference with circulatory efficiency ensues, and total collapse is inevitable.

Add the fact that this collapse comes practically always without premonitory symptoms of any kind, and the very great danger to the aviator becomes apparent. There is a total reversal of conditions from those of heart strain from vigorous exercise, in which the intense discomfort caused by overexertion gives ample warning that one is approaching the limit, and in which at worst partial failure of the heart would do

* From the Medical Research Laboratory, Air Service, Mineola, L. I.

no more than make further exertion impossible, and so automatically terminate the strain.

This vicious circle may satisfactorily explain many cases of sudden fainting at low altitudes. For if there were a momentary failure of coronary circulation due perhaps primarily to a wholly neurotic influence on the vasomotors, a condition of undernourishment of the heart would be started that would be rapidly cumulative.

The elements of strength in meeting the situation are a strong heart muscle, efficient and accurately adjustable coronary circulation, and the ability of the peripheral vasomotors to allow increase of blood flow to the parts that need it without undue strain on the heart by increased blood pressure. These arterial reactions demand in the first line perfect anatomic condition of the vascular walls and perfect vasomotor control. As a consequence, two classes of cases are found that are most likely to react badly to lowered oxygen tension: men who have any arterial change in the way of sclerosis, and those with poor vasomotor control.

The latter class includes numerous individuals who are either overvigorous in their reactions and run a high blood pressure (often high strung, efficient people) or who have fluctuations of vasomotor tone which are manifested in a variety of ways but eventually lead to an identical result, namely, circulatory collapse and fainting, usually following marked dilatation of the heart.

The "optimum" type of individual will go to extreme heights with practically no signs of circulatory difficulty, and will at the end become unconscious from direct effect of oxygen want on cortical centers, giving quite a different picture from that of circulatory collapse.

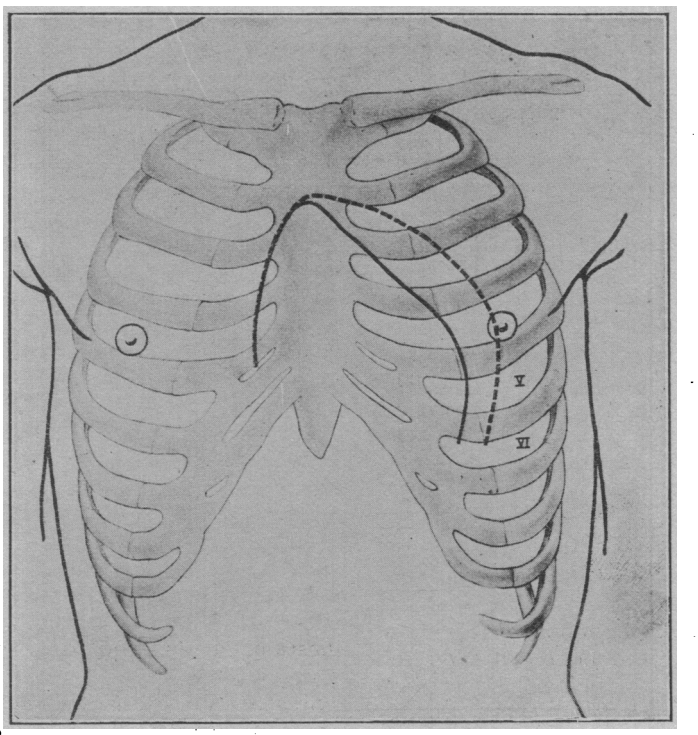

Fig. 2.—Dilatation of the heart at 18,000 feet when man was in poor condition; when feeling well, this man could go 5,000 feet higher without any ill effects: solid line, outline of heart before and after experiment; broken line, heart outline to percussion at elevation of 18,000 feet.

FAILURE TO COMPENSATE

Paradoxically enough, the poorer types of organisms also fail to show heart strain and dilatation. Persons of poor physical and sluggish reactions, whether by nature or because of sedentary life and lack of exercise, ordinarily show a more or less marked failure of the compensations demanded for efficient existence under the altered conditions. They show little or no quickening of the pulse, and no change, or even a fall, in blood pressure. They simply become inefficient instead of making the strain.

Many types with defective hearts and blood vessels do not show heart strain because, having tried to meet the requirements, and having found it impossible, they give up the fight and fail.

Those who do show it, as previously suggested, are persons of vigorous reactions, especially high strung types, but are often "out of condition" for one reason or another. The influence of factors of condition, which are too often underestimated, has been found to be very great. Dissipation, nerve strain, slight infections, may involve heart weakness or abnormal vasomotor reactions which overstrain or undernourish the heart, and thus cause the aviator's death.

CONDITION

The influence of "condition" is a point of the greatest practical importance, of course. One of our hardiest subjects illustrated this. He had been in the low-pressure chamber on one occasion at an elevation of 23,000 feet for some minutes and remained in practically perfect condition. The following day the experiment was repeated; but on the evening between he had dined late with friends, with the usual but not excessive accompaniments. When the altitude of 18,000 feet was reached on the second test he was found to be completely inefficient; he was markedly cyanotic; his heart was dilated 3 cm., and the heart sounds were of very poor quality. He would have collapsed in another minute if oxygen had not been administered.

The question of just what is involved in "good condition" has received much consideration. On the basis of our present knowledge, the most important element seems to be normal vasomotor control, that is, adequate nourishment of the tissues with a minimum of strain on the heart. In this the coronary circulation is of first importance. Other factors are, doubtless, the strength and condition of the heart muscle and probably certain matters of general metabolism, for example, the ability to generate energy rapidly without the accumulation of harmful waste products.

The practical result of this knowledge of the strain on the circulatory system involved in aviation, and the paramount importance of "condition," bear on both the selection and the maintenance of the flying personnel. Only those men should be allowed to fly who possess faultless circulatory systems; and once in the service, aviators deserve the most scrupulous oversight to keep them in as perfect condition as a well-trained football team, and to prevent them from going into the air when they are not in condition.

LOW OXYGEN AS A FUNCTIONAL HEART TEST

As far as the selection of men with perfect circulation is concerned, we possess fortunately a wonderful diagnostic agent in the low oxygen test, to which eventually all flyers will be subjected. We have come to

regard the Henderson rebreathing apparatus as affording by far the most efficient test of the heart, from both anatomic and functional points of view, that we possess.

The strain of making good for low oxygen tension in the atmosphere is so great that any latent defect, fully compensated and not to be discovered by ordinary methods of examination, becomes glaringly apparent during a rebreathing test.

The question of anatomic condition of the valves, however, is not the only consideration with regard to a heart. Many a damaged heart will compensate so well, as the result of the quality of the heart muscle, that its functional power may even be above normal. Clinicians have long been searching for a functional heart test which would tell them, not what the heart was anatomically, but what it could do. In the low oxygen methods we have just such a test, and it should be of great value in ordinary clinical work.

In the case of well compensated valvular disease, murmurs develop under low oxygen or become much stronger, and accentuation of heart sounds takes place, indicating hypertrophy of the left ventricle or back pressure through the lungs; the blood pressure is high and the heart is evidently overworking seriously. Often in young men such a heart will be fully as successful as a normal one in meeting the demands made on it in ordinary life; in fact, overcompensation is the rule rather than a failure to compensate. But under the low oxygen test the underlying defect is revealed.

In the case of valvular lesions that are less well compensated, the heart is more readily reduced to incompetence; after the period of overwork there is marked cyanosis, excessive discomfort, and insufficiency of the peripheral circulation, most delicately shown by inability to perform well on the psychologic apparatus that forms part of the rebreathing test.

In subjects with arterial disease there is a more or less marked rise in blood pressure owing to inability of the peripheral vessels to make way for the increase of blood flow without throwing a much increased strain on the heart. At the same time there is doubtless insufficiency of the coronary circulation as well, so that between high blood pressure and poor nutrition the heart muscle soon becomes incompetent; the heart sounds deteriorate rapidly in quality, and the peripheral circulation becomes insufficient.

Tendencies to arrhythmia are brought out in a remarkable way by the rebreathing apparatus: several hearts that showed at the start only an occasional extrasystole have become arrhythmic to a degree that was positively alarming. We suspect that there is the possibility of danger in this method of examination for hearts showing difficulty of conduction or in which there is a possibility of the development of ventricular fibrillation.

One of the most gratifying features of this work has been the direct bearing of the observations on fundamental questions of circulatory physiology and pathology. In this way they go far beyond the narrow field of aviation medicine in their scope. It is impossible here to discuss thoroughly the many side-lights thrown on clinical medicine. A few of these points may, however, be briefly mentioned.

One is the supreme importance of normal vasomotor control in connection with circulatory efficiency, which means general efficiency as well. Abnormal vasomotor reactions mean either high blood pressure with excessive heart strain if the demands on the circulation are met, or inefficiency if the demands are not met.

The behavior in the test of subjects with more or less marked arteriosclerosis has been of the greatest value in understanding the effect of arterial change[1] under conditions of ordinary life. An interesting fact is brought out by the behavior in the test usually shown by subjects in their thirties, which suggests that arterial change at this age is commonly already considerable. This may account to a large degree for the well known fact that 20 is the best age for flyers, and that every year above this decreases the likelihood of their being able to stand the strain of hard service.

The relation of nerve tension to vasomotor control is a subject on which we have been able to throw some light, and our results fit in well with the demonstration by the British commissions of the intimate relation of the vasomotor system to shell shock, trench neuroses, irritable heart and allied conditions that have contributed so largely to the disabilities of this war. The frequency with which slight cardiac lesions have been demonstrated among presumably healthy men has been striking. Even among a class of men as carefully picked as American aviators we have found more than 5 per cent. These were usually cases that could hardly have been demonstrated by ordinary means of examination, and would have passed the most rigid inspection as "functional heart murmurs" or at worst as borderline cases with a wide margin of safety. Every one who has worked on the Army cardiovascular boards knows how common and how troublesome such cases are; and the British experience shows that men who genuinely have slight organic lesions will not stand up under modern war conditions. For this kind of work the low oxygen test should be of the greatest value.

Similar to this class of cases are "athletic hearts," which we have very frequently encountered among aviators, who are to a large extent drawn from the ranks of college athletes. Such hearts behave very badly under low oxygen. They show high blood pressure, marked heart strain, with exhaustion and eventual collapse. Without entering into any discussion of the question, it may be said that our evidence points strongly to the belief that the so-called "athletic heart" represents not a faulty involution of a normally hypertrophied heart, but a heart that has either been definitely injured by strain, or one with an underlying vascular lesion too slight or too well compensated to be discovered. We have demonstrated slight old mitral insufficiency in several men whose names are familiar on the sporting page of the papers.

1. See Chart 2 in the preceding paper of this series.

Quackery on Both Sides of the Ocean.—Under this heading Dr. Pinkhof comments in the *Nederlandsch Tijdschrift* on the efforts made by the osteopaths to get appointed to the medical corps of the United States Army. He says:. "Dr. Gorgas and his staff are better antimonopolists in fact than the legislators in our land (the Netherlands). Our legislators would like to provide a monopoly for the quacks, that is, to confer on them the exceptional privilege of practicing medicine without fulfilling the conditions which every honest citizen has to fulfil. At a recent representative meeting of the organized pharmacists of the Netherlands, the chairman, H. L. Visser, gave a good definition of quackery which may well be taken to heart by every one. He said, 'Quackery, whatever its form, is a gambling game, with life for the stakes and health as the highest prize.'"