The influence of barometric changes upon the body in health and disease / by Andrew H. Smith.

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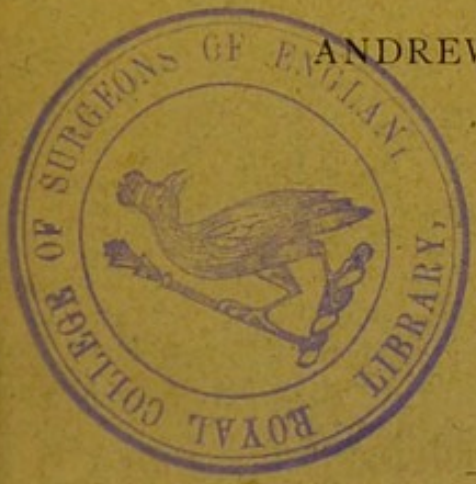
NEW YORK



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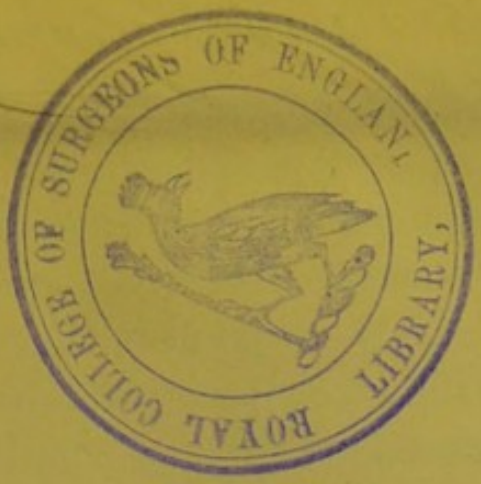

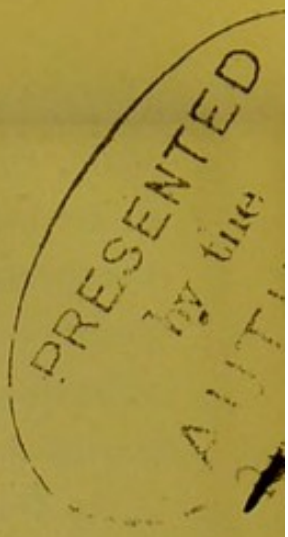

THE INFLUENCE OF BAROMETRIC CHANGES UPON THE BODY IN HEALTH AND DISEASE.

By ANDREW H. SMITH, M.D.,

NEW YORK.

THE effect upon the body, in health and disease, of variations in barometric pressure, is a subject which has not received the attention from the profession which its importance entitles it to. Beyond some studies of the effect of altitude upon phthisis and the influence of barometric changes in determining pulmonary hemorrhage and attacks of spasmodic asthma, but little discussion seems to have been excited. Even the introduction of compressed and rarefied air as therapeutic agents appears to have done very little to stimulate inquiry as to the part played by the constant natural changes in the density of the atmosphere in preserving health or inducing disease. Yet these changes cannot be without their influence, and there is opened here a wide field, not only for speculation, but for scientific observation, which may bring important accessions to our knowledge of the etiology of those affections which appear in the form of attacks recurring at irregular intervals.

The introduction, within a comparatively few years, of the use of compressed air in submarine engineering opera-

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tions, has given an opportunity for studying, on a large scale, the effect of a prolonged sojourn in a greatly condensed atmosphere, and of the subsequent removal of the pressure. The facts observed are very suggestive, and point unmistakably to a disturbance of the normal distribution of the blood with each change in the pressure of the atmosphere.

As the result of exposure for several hours to a pressure of two or three atmospheres, there may be developed a group of morbid phenomena to which the writer, in an essay published some years ago,[1] attached the name of the Caisson Disease. The definition of this disease is as follows:

A disease, sometimes fatal, depending upon increased atmospheric pressure, but always developed after the pressure is removed. It is characterized by extreme pain in one or more of the extremities, and sometimes in the trunk, which may or may not be associated with epigastric pain and vomiting. In some cases the pain is accompanied by paralysis more or less complete, which may be general or local, but is most frequently confined to the lower half of the body. Cerebral symptoms, such as headache, vertigo, and coma, are sometimes present. The above symptoms are connected, at least in the fatal cases, with congestion of the brain and spinal cord, often resulting in serous or sanguineous effusion, and with congestion of most of the abdominal viscera.

That such decided results, including even death, may be brought about by extreme changes of atmospheric pressure, certainly leaves room for the surmise, that slighter changes, occurring from natural causes, may produce, at least, proportionate effects. I think that the essay already referred to, contained the first suggestion, that this might be the explanation of the neuralgic pains which many persons complain

[1] Essay on the effects of high atmospheric pressure, including the caisson disease. Published by the East River Bridge Company, 1873.

of at the approach of a storm, and which are generally ascribed to the *moisture* in the atmosphere.

A study of the mechanism, by which the congestions observed in the caisson disease are produced, will serve to illustrate the action upon the system of the comparatively trivial changes of the barometer, just as the effect of drugs, taken in excessive or poisonous quantities, may throw light upon their action in medicinal doses.

It is obvious, that, if the blood were exposed to an equal pressure in all parts of the body, there would be no change in its distribution. It is equally clear, that the blood, if free to move, will pass from a place where the pressure is greater to one where it is less. The body is made up of structures of different densities, which present a varying resistance to compression. But, permeating these structures in every direction, are vessels in perfect communication throughout the entire system, and filled with a mobile fluid which is free to change its locality in obedience to any force which is brought to act upon it. Now, when the surface of the body is subjected to an even pressure on all sides, the tendency is to a distribution of this pressure toward the centre. If the body were composed entirely of solids, this could be effected only by the compression of those solids, and a point would very soon be reached, where the resistance would balance the compressing force, and the parts lying more toward the centre would remain unaffected. But the presence of a fluid in the structures, with free channels in which to move, changes all this. While the solid tissue resists compression, the fluid blood retreats from the surface to the centre, and accumulates there, until an equilibrium of pressure is produced.

Hence, we deduce the law, that under high atmospheric pressure, the centres will be congested at the expense of the periphery.

But, aside from location, vessels coursing through dense and resisting organs, will be less exposed to external pressure than those passing through soft and yielding structures. Hence, a second law, that firm and compact structures will be congested at the expense of those more compressible.

But there are structures, very soft and yielding in themselves, yet enveloped in a rigid casing of bone which entirely shuts off the influence of external pressure. Hence, the establishment of the equilibrium in them is wholly dependent upon an afflux of blood. This gives us the third law, that structures within closed bony cavities are congested at the expense of all others.

In accordance with these laws, we shall find, that, while in the caisson, the condition of the different parts in regard to the supply of blood will be as follows:

The skin and the superficial structures will be anæmic.[1] The central portion of the limbs and the interior organs of the body will be congested. The solid viscera of the abdomen will be especially engorged, on account of both situation and structure. The brain and spinal cord and the interior of the shaft of the long bones, will be congested to a high degree from the operation of the third law.

These changes are not perfected until a considerable time has been passed in the compressed air. The circulation, up to this point, goes on everywhere with vigor, the change being in the relative calibre of the vessels, not in their tension. The counter-pressure becomes uniform throughout the whole vascular system, but this counter-pressure supersedes the natural muscular resistance or *tone* of the vessels, which have become passive tubes. The blood is distributed, not in accordance with the physiological demands of the different parts, but in obedience to overpowering physical force.

[1] This is shown by the pallor which is very characteristic.

This is the condition of the circulation at the moment that the process of locking out begins. Yet the changes which have taken place up to this point are not the cause of the morbid phenomena which constitute the caisson disease, else the attack would take place while *in* the compressed air, instead of after leaving it. It is evident that the *removal of the pressure*, and not the pressure itself, is the immediate cause of the seizure.

This removal is effected in the few minutes which are occupied in locking out.[1] But it is not to be supposed that the vessels will instantly assume their normal condition. They are in a state of relaxation, not only in the congested, but also in the anæmic parts; in the former, because of over-distension; in the latter, because the muscular coat cannot at once recover from its inaction. The aggregate capacity of the vascular system will, therefore, be in excess, compared to the volume of blood to be conveyed; or, in other words, there will be a lowering of vascular tension.

Hence, the circulation will be languid, and the congested parts will not readily empty themselves of the excess of blood which they contain. Especially will this be the case in the brain and spinal cord, where the conditions are most favorable for the production of congestion. The capillaries being clogged with effete blood, the nutrition of the part must suffer, and disturbance of function will result.

It is to this, I think, that the delirium and the transient loss of consciousness, which occasionally occur, are to be attributed. When the spinal cord is the seat of this condition, pain in the parts deriving their nerves from that section of the cord may result, or paralysis, more or less complete, may follow.

This appears to me to account for the phenomena in those cases, in which the local symptom is paralysis, or pain

[1] *I. e.*, passing from the caisson into the open air, through the air-lock.

of a transient or shifting character. These cases may, I think, be considered as entirely spinal in their origin. But, in many cases, there are evident local changes, such as tumefaction, rise of temperature, etc., which indicate local irritation, and which are probably due to obstruction of the vessels of the part as a sequel to the local congestion. This explanation is applicable also to those cases, in which the pain is fixed in one locality, which may be very much circumscribed, and where it persists for days without intermission, feeling, as the patient expresses it, "as if it were in the bone," where it very likely is. Such a pain presents a marked contrast to those shifting pains which have been described, and, if considered of spinal origin, would indicate a serious lesion confined to a minute portion of the cord. That such a circumscribed lesion might occur as a very rare exception, must be admitted ; but that it should be present in a considerable proportion of cases, is, in the last degree, improbable.

The testimony of all observers is, that the liability to attack is directly as the duration of the stay in the caisson. This admits of an easy explanation on the theory which I have advanced. The more thoroughly the system has become adapted to the change in the circulation, the less readily it will resume its normal condition, when the pressure is removed. The congested vessels, especially, will lose their contractility in proportion to the time their muscular fibres have been upon the stretch.

Now it is evident that the changes in the circulation which take place in the caisson must occur, to some extent, whenever there is a rise of the barometer, and, conversely, that a fall of the mercury must result in changes similar in kind, however slight in degree, to those attending a change from the caisson into the open air. But it may be argued, that the phenomena of the caisson disease

require a change of pressure so enormously disproportioned to any changes occurring from natural causes, that it would, be absurd to reason from one to the other. But the fact is, that observation of the effects of high pressure reveals a difference in the susceptibility of different persons to its influence which would not, *a priori*, have been expected, and which becomes a prime factor in calculating the effect of minor degrees of condensation of the atmosphere.

Of the men employed under my observation in the caissons of the East River Bridge, a large proportion bore the excessive pressure (reaching at last to 36 lbs. additional to the square inch) without the slightest ill effect; while, on the other hand, some quite severe cases resulted from a very short exposure to the slight pressure employed in the early part of the work. For instance, a student of engineering visited the Brooklyn caisson, where the pressure did not exceed 15 lbs., and, after a very brief stay, was seized, on coming into the open air, with temporary paralysis. That a short exposure to a pressure of 15 lbs. should paralyze one man, while another was able to bear, day after day, without inconvenience, a pressure of 36, or even, as at St. Louis, of 50 lbs., is to be accounted for only by assuming a vast difference in susceptibility, the limits of which difference in either direction can only be surmised. Back of this there is probably a difference in the efficiency of the vaso-motor system, or, perhaps, in the structure of the vessels themselves, so that, in one case, the vessels resume, at once, their normal condition, when the pressure is removed, while in the other, the abnormal distribution of the blood persists in certain localities.

Whatever the predisposing condition may be in this latter class of cases, we have only to assume its existence in an exaggerated degree, to bring the subject within the range of the influence of ordinary barometric changes. If

one man can bear a change of 90 inches without feeling it, while another is paralyzed by a change of 30 inches, it is not incredible, that a third may have aching limbs as the result of a fall of 2 inches.

In point of fact we know, that there are many persons who can foretell, by their sensations, the approach of a storm, and who are in the habit of saying, "We shall have rain to-morrow; I feel the dampness in my bones." Now the proof, that the moisture in the atmosphere is not the cause of their suffering is found in the fact, that a sudden shower may saturate the earth and fill the air with dampness, without causing them to complain, nor do they feel any ill effect from exposure to the falling dew. But, whenever the glass goes down, though the air may not be sensibly damp, they experience more or less discomfort. In such persons the action, as before suggested, is probably similar to that observed in a greatly intensified degree in the caisson disease. The change from a higher to a lower degree of atmospheric pressure disturbs the circulation in a way to affect certain nerve cells or nerve fibres; the individual having a strong natural or acquired predisposition, a "neuralgic habit," which needs but the slightest cause to develop a greatly disproportioned effect.

This predisposition, or habit, may consist simply in the existence along a nerve, or at its origin, of a point, at which the capillaries are, for some reason, more than usually distensible. Such a condition of the cutaneous capillaries is seen sometimes in children who have a mother's mark that has so faded as to be imperceptible, except when the child cries, when it becomes plainly visible. Some cicatrices, also, present the same conditions, a key, perhaps, to the neuralgias following gunshot wounds, which are especially prone to be affected by changes of weather.

A curious fact, however, in regard to the terrific pains of

the caisson disease is, that they are often not felt, until several hours after coming into the open air. In these cases, it is probable, that the area of capillary obstruction does not, at first, include a centre of pain, but that it widens, as all capillary disturbance is disposed to do, until such a centre is reached.

This delay in the development of neuralgia from lessening of pressure, would tend to obscure the study of cases in connection with barometric changes,[1] the pain, perhaps, coinciding in point of time with a rise, though caused in reality by a fall, of the barometer.

No one can have failed to remark the difference which we feel in our mental and bodily efficiency in different states of the weather. On clear, bright days the brain is active, the muscles vigorous, and the internal organs appear to work smoothly. On damp and foggy days, on the contrary, mental effort is irksome, the limbs drag, the appetite is less, the digestion slower, and the whole tone of the system is lowered.

This difference may be explained, at least in part, on the principle under discussion. When the air is clear, the barometer is usually high, and the greater pressure upon the surface drives the blood to the interior of the body, and especially to the organs in closed cavities—such as the brain, and to solid and dense organs—such as the liver and kidneys, thus stimulating their functions. At the same time, the pressure assists the muscular tone of the vessels in diminishing the total vascular area, and thus insuring celerity of the blood current everywhere. But when the pressure falls, as it does in damp weather, the peripheral vessels, deprived of a part of their support, yield to distention, and there is a transfer of blood to them from the more central organs, and, at the same time, a general slowing of the circulation, all resulting in lessened vital energy.

[1] For a very interesting study of this kind, see a case reported by Dr. Weir Mitchell, *Am. Jour. of Med. Sci.*, Jan., 1877.

How much these changes have to do with initiating disease, is a question which opens a wide field for conjecture. That increased pressure on the surface might be sufficient to determine the rupture of a miliary aneurism in the brain, is easily conceivable. That diminished pressure might concur with other causes in bringing about internal congestions and inflammations, is at least probable; and that the lowered vital tone from a sudden fall of the barometer may render the system an easier prey to other causes of disease, is a justifiable inference.

There are many forms of disease that recur at irregular periods in persons susceptible to them, the subject being, in the intervals, apparently in perfect health. There are, evidently, in these cases a predisposing cause, which is permanent, and an exciting cause, which is transient. The former is inherent in the individual; the latter is some influence operating from without. Neither is capable alone of producing an attack, their joint action being required.

The predisposing cause, for the most part, eludes our observation. The exciting cause is often sufficiently apparent and may be error in diet, exposure to cold, over-fatigue, mental excitement, etc. But sometimes the strictest inquiry fails to elicit the cause, although some must have existed. That some, at least, of these cases are attributable to such disturbances of the circulation as have been mentioned as depending upon change of atmospheric pressure, appears to me to be more than likely.

At this time, when the state of the barometer at any given hour is a matter of permanent record, accessible to all, it would not be difficult, especially in hospitals, to compare notes of cases with barometric tables, and results of great scientific value might be obtained.