SCIENCE

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RECENT PROGRESS IN OUR KNOWLEDGE OF THE PHYSIOLOGICAL ACTION OF ATMOSPHERIC CONDITIONS[1]

Two weeks ago to-day, in the physiological laboratory of the Columbia School of Medicine, Dr. Fred W. Eastman and I made the following experiment: A young man, twenty-one years of age, in excellent physical condition, who was willing to act as the subject of our tests, was dressed in light underclothing and light trousers, a sweater, stockings and shoes. His systolic and diastolic blood pressures and his pulse rate were taken in the sitting posture; the carbon-dioxide content of the alveolar air of his lungs was determined; a pneumograph was attached to his chest for recording his respiratory movements; a resistance thermometer was placed in the rectum and connected with a self-writing galvanometer for the continued record of his bodily temperature; and a flat-bulbed thermometer was strapped firmly to his forehead to serve as an indicator of the temperature of his skin. Thus equipped he entered a small chamber, provided with a door and windows and with facilities for heating and humidifying the air. He remained there, sitting quietly, for a period of four and one quarter hours. The temperature of the air in the chamber was raised as quickly as possible above the temperature of his body and reached a maximum of 43.3° C. (110° F.) with a maximum wet-bulb reading of 37.2° C. (99° F.), while the relative humidity was increased to a maximum of 85 per

[1] Read before the American Pediatric Society, Washington, D. C., May 8, 1916.

cent. For a period of two and one quarter hours the door of the chamber was kept closed, although it was not wholly air-tight, and the unusual atmospheric conditions were maintained, although not continually at their maximum. Afterward the door of the chamber was opened and the air within was allowed to acquire the more comfortable conditions of the room air outside, which possessed a temperature of 18° C. (64.5° F.) and a relative humidity of 51 per cent. During the whole time of the experiment a continuous record was made of the subject's bodily temperature; at intervals of fifteen minutes measurements were made of the temperature and the humidity of the air of the chamber, of the temperature of the subject's mouth and of the skin of his forehead, and of the rate of his pulse and his respiration; at intervals of every hour his systolic and diastolic blood pressures and the carbon dioxide content of his alveolar air were determined; while occasional records were made of the carbon dioxide content of the air of the chamber and of the subject's sensations. The results of the experiment will be discussed later. It is typical of many experiments, similar in object although differing in details, which have been performed in recent years inside and outside many laboratories in an endeavor to discover the relations of the individual to the air that surrounds him.

As one result of these experiments there has been a great change in our ideas concerning the physiological action of atmospheric conditions. It had long been the custom to ascribe to chemical components of the atmosphere the bad effects of living in air that had already been breathed by human beings. The discovery of oxygen and of carbon dioxide early in the last century gave a great stimulus to this notion, and it became firmly fixed in the minds of chemists, physiologists and physicians, as well as the educated masses, that air that had been breathed was vitiated chemically and rendered unfit for human use by the lack of oxygen, the accumulation of carbon dioxide, and the presence of an organic poison of unknown nature. No sooner had this notion become widely accepted than the laboratories began to demonstrate the inadequacy of the supposed proof of the notion, and—to cut a long story short—we now know that, except under very unusual circumstances, the harmfulness of respired air is not due to its chemical components. By respiration oxygen can not be reduced to a deleterious proportion nor can carbon dioxide be produced in deleterious quantity, except under very unusual conditions of living; and the organic poison of respiration has no real existence. The harmfulness of living in confined air is found in certain physical rather than chemical features—the air is too warm, too moist, and too still; and if it has not these physical features it is not harmful.

We all have sat in crowded assemblies; we all have experienced the hot, humid, still days of an American summer. We all know the effects of such air on our sensations—the general bodily discomfort, the sleepiness, the flushed face, the headache, the disinclination to think or to act, the general debility, the longing for relief. But sensations are an inadequate measure of bodily conditions. In what respects is hot, humid, still air harmful? To answer this question we must consult the records of many researches, chiefly on human beings, but partly on animals, that have been undertaken since Hermans,[2] more than thirty years ago, observed that in crowded theaters and churches his own bodily temperature rose. The most recent of these researches is that of the New York State

[2] Hermans, *Arch. f. Hyg.*, I., 1, 1883.

Commission on Ventilation,[3] which has been in progress for the past two and one half years and is not yet completed.

Notwithstanding that man is supposed to be a homothermal organism, there is a certain relationship between his bodily temperature and the temperature of his environment, even under the ordinary conditions of living. This has been shown by the New York Commission, which found that during the months of June and July the rectal temperature of its subjects at 8 A.M., living in their own homes, was conditioned by the average atmospheric temperature of the preceding night. If the night had been warm the bodily temperature in the morning was high; if cool, the bodily temperature was low. The variation of bodily temperature was about 0.55 degrees C. (1 degree F.) for 20 degrees of atmospheric temperature, although it is probable that the degree of variation can be modified by the clothing. The commission further found that, whatever the bodily temperature of its subjects might be at the beginning of an experiment, it was lowered by confinement in an atmosphere of 20° C. (68° F.) and 50 per cent. relative humidity, and raised by confinement at 23.9° C. (75° F.) with the same humidity, or still more by 30° C. (86° F.) with 80 per cent. humidity. The final average bodily temperatures in certain series of observations, where the subjects were confined in the observation chamber for from 4 to 7 hours were as follows:

After 20° C. (68° F.), 50 per cent. humidity, the average bodily temperature was 36.7° C. (98° F.).

After 23.9° C. (75° F.), 50 per cent. humidity, the average bodily temperature was 36.9° C. (98.5° F.).

After 30° C. (86° F.), 80 per cent. humidity, the average bodily temperature was 37.4° C. (99.3° F.).

Haldane[4] and others have shown a greater elevation of bodily temperature in more extreme atmospheric conditions, and have pointed out the accompanying dangers of heat stroke. Eastman and I have seen the temperature of a normal adult man rise 3.3° C. (6° F.) during a stay of three and one quarter hours in an atmosphere averaging 40.4° C. (104.7° F.) in temperature and 95 per cent. in relative humidity. The relation between bodily temperature and external cold has not been so fully studied, but enough is known to warrant the statement that, in normal individuals at least, the bodily temperature can be to a considerable degree controlled by controlling the temperature and the humidity of the surrounding air. It is altogether probable that the same is largely true in febrile diseases.

External temperature exerts likewise a definite effect on the circulatory system. The rate of the heart beat is increased in warm, humid, and decreased in cool, dry air. The New York Commission found the average rate of its subjects confined in an atmosphere of 30° C. (86° F.) and 80 per cent. relative humidity to be 74, and in an atmosphere of 20° C. (68° F.) and 50 per cent. humidity to be 66. Eastman and I have seen the pulse rate increase by 39—from 67 to 106—as the temperature of the air surrounding the subject rose from 23.3° to 43.3° C. (74° to 110° F.) and the humidity from 58 to 90 per cent.

The important and involved topic of the

[3] C.-E. A. Winslow (chairman), D. D. Kimball, Frederic S. Lee, J. A. Miller, Earle B. Phelps, E. L. Thorndike and G. T. Palmer (chief of investigating staff). The results of their investigations have yet been published only in part. For a general presentation of some of the results see *Am. Jour. of Public Health*, V., 85, 1915.

[4] Haldane, *Jour. Hyg.*, V., 494, 1905. Haldane, Pembrey, Collis, Boycott and Cadman, Rep. Dept. Com. on Humidity and Ventilation in Cotton Weaving Sheds, London, 1909 and 1911.

relation of atmospheric conditions to blood pressure I must leave until the abundant data that have been accumulated by the New York Commission have been subjected to a more careful examination than has yet been possible, although it may be said that excessively high temperatures and high humidities are accompanied by an elevation of both systolic and diastolic pressures. A study of the commission's records by one of the various methods for evaluating vascular data seems to reveal another fact of distinct importance. When the human body rises from a recumbent to a vertical position the threatened settling of the blood into the lower parts by gravity, with the resultant deleterious effects, ought obviously to be counteracted. In the healthy person the most expedient way to accomplish this is by means of a vigorous vasomotor mechanism acting to constrict the arterioles and raise the blood pressure. This mechanism is assisted by a quickening of the rate of the heart's beat. If the mechanism be enfeebled from any cause, there may be, along with the change of posture, a lessened rise of blood pressure, or even a fall, and a great increase in the heart rate. A comparison, therefore, of the change in the systolic blood pressure and the change in the rate of the pulse resulting from a change of the position of the body from the horizontal to the vertical gives a clue to the efficiency of the vasomotor mechanism. On this basis Crampton[5] has constructed a scale of percentages of vasotone. In terms of this scale the New York Commission finds that the vasotone diminishes in hot and humid air, and increases as the air becomes cooler and dryer. Thus these results indicate that a distinct vascular benefit follows from exposing the body to a cool dry air.

Atmospheric conditions exert on the respiratory system effects of various kinds. On the rate of respiration a moderate degree of heat and humidity seems to be without effect, but more extreme conditions cause a quickening of the breathing, and this is probably accompanied by more shallow respirations. The more extreme conditions too appear to result in a lowered concentration of carbon dioxide in the air of the pulmonary alveoli, although I can not yet quote actual figures to demonstrate this. The matter, however, is important, since a lowered alveolar carbon dioxide may signify an increased content of hydrogen ions, in other words increased acidity, in the blood. Eastman and I are now investigating this point with much interest.

The mucous membrane of the respiratory tract is markedly affected by atmospheric conditions. This was shown three years ago by Hill and Meucke,[6] and it has recently been quite fully investigated by Miller and Cocks[7] under the auspices of the New York Commission. Exposure to heat causes increased swelling, redness and secretion in the nasal mucosa, and these effects are more marked when the humidity of the air is high. Exposure to cold reverses the effects. When the subject passes from a cool to a hot room and a current of air is played upon the face there occurs a diminution of the swelling and the secretion; but passage from a hot to a cool room with a similar draught results in increased swelling and increased secretion. This latter condition seems to be especially favorable for the development of infectious microorganisms. But the causative relation of the bacteria of the nasal mucosa to "colds" seems to be still in doubt.

The distaste for physical labor which we feel on a hot humid day is a common experi-

[5] Crampton, *New York Med. Jour.*, 98, 916, 1913.

[6] Hill and Meucke, *Lancet*, 1291, 1913.

[7] Miller and Cocks, *Trans. Am. Climatol. and Clin. Assoc.*, 1915.

ence, and it is often interpreted as real inability to work. The New York Commission found, in their experiments with human beings, that, if pushed, the individual is capable of performing as much muscular work in an atmosphere of 30° C. (86° F.) and 80 per cent. relative humidity as in one of 20° C. (68° F.) and 50 per cent. humidity, but that he is not inclined to do so much. The lack of exact knowledge as to what the muscles themselves apart from the nervous system can do under such circumstances induced Scott and myself[8] to investigate the subject on animals. Taking the comfortable condition of 20.6° C. (69° F.) with 52 per cent. relative humidity as our standard, we found that when cats were confined for six hours in a well-ventilated chamber, the air of which was kept at an average temperature of 32.8° C. (91° F.) and an average humidity of 90 per cent., the excised muscles of the animals lost in the length of their working period before exhaustion 11 per cent. and in the total amount of work which they were able to perform 24 per cent. At an intermediate temperature and humidity they lost in an intermediate degree. These results indicate that the distaste for physical labor which is felt on a hot and humid day has a deeper basis than mere inclination—the muscles themselves are actually incapable of performing as much work. We found, moreover, that in the extreme condition the blood lost as much as 6 per cent. of its sugar, and 2 per cent. when the intermediate condition was maintained. There is evidently correlation between decreased blood sugar and decreased muscular power, and we have suggested that a physiological adaptation is here indicated, such that "when it is physiologically fitting that the animal reduce muscular exertion to a minimum, in order that the output of heat may be as low as possible, as in a hot and humid environment, the supply of fuel will be lowered correspondingly."

[8] Lee and Scott, *Am. Jour. of Physiol.*, XL., 486, 1916.

Little can be said at present regarding the action of atmospheric conditions on the nervous system. The rise of external temperature by dilating the cutaneous blood vessels undoubtedly makes the brain anemic, but it is not certain that variations in such temperature with or without variations in humidity markedly affect the action of the nerve tissues, unless the variations are excessive. The New York Commission, under the lead of Thorndike, has expended much time and effort in endeavors to detect a possible influence of atmospheric variations between moderate limits on the ability to do mental work. The subjects were given such psychological tests as cancelling arithmetical figures, adding figures, mentally multiplying three-place by three-place figures, typewriting, and more complex mental performances which involve choice and judgment. The range of atmospheric variation was from a lower limit of 20° C. (68° F.) and 50 per cent. relative humidity, and an upper limit of 30° C. (86° F.) and 80 per cent. humidity. In some cases the air was quiet, in others it was kept in motion by electric fans. The tests continued for periods of from 4 to 7 hours and in some cases they were repeated for 6 successive days under the same conditions. In neither the young men nor the young women subjects of these tests could there be detected any relation between atmospheric conditions and either the accuracy or the amount of the mental work that was performed. A series of experiments on a larger scale has been instituted, but is not yet completed.

The relation between atmospheric conditions and metabolic phenomena is not yet elucidated. During the summer of 1914 the

New York Commission made a partial study of this topic on human beings with the assistance of Mr. H. L. Higgins, then of the Carnegie Nutrition Laboratory. The tests employed included such subjects as total metabolism or total heat production, the metabolism of carbohydrate, and the metabolism of protein. The results were almost wholly negative. They can not, however, be regarded as conclusive. As regards lesser specific changes in metabolic processes, too, little can be said at present. But the facts that external cold increases metabolism, that profound metabolic changes occur in the fevers of infection and that there is some evidence that in hyperthermy produced in other ways than by infections metabolism is altered, lead us to suspect that it may be changed, not only totally but in specific details, with even moderate changes in the surrounding atmosphere. It is difficult to believe that a relationship that is so amply demonstrated for the physical phenomena of the body does not involve also its chemical performances.

A further topic that is inviting is the possible relationship between atmospheric conditions and bacterial infections. Most of the experimental observations that have here been made relate especially to the action of temperature on the course of infections, and it has generally been found that high external temperature with accompanying pronounced increase of bodily temperature checks the progress of infections that are already existing. Somewhat lower temperatures (30°–35° C., 86°–95° F.) on the other hand, seem to favor the multiplication of the bacteria and the advance of the disease. In the experiments of Winslow, Miller and Noble,[9] of the New York Commission, in which rabbits were confined in air of from 29° to 32° C. (84.2°–89.6° F.) there was, in the first three weeks, a distinct decrease in the formation of hemolysins when the animals were compared with control animals kept at lower room temperatures. Similar but less striking results were obtained in the formation of agglutinins.[10] It thus appears that external temperatures up to about 30° C. (86° F.) are unfavorable to the development of immune bodies in the blood. Miller and Noble,[11] of the New York Commission, found, furthermore, that respiratory infections of rabbits with *Bacillus bovisepticum* (snuffles) is favored by the chilling of such animals after they have been accustomed to heat, and some of their results suggest that a change from a low to a high external temperature also predisposes to similar infection. Although Chodounsky[12] obtained only negative results, the weight of the recent experimental evidence favors the view that exposure of the body to cold is favorable to the incidence of acute respiratory disease, and it appears not improbable that the primary seat of this deleterious influence is in the mucous membrane of the upper air passages.

No review of recent progress in our knowledge of the relation of man to the atmosphere would be complete if it failed to take note of the striking observations of Mr. Ellsworth Huntington, which are set forth in his engaging book on "Civilization and Climate."[13] Mr. Huntington made a careful study of the output of industrial workers in various factories in the state of

9 Winslow, Miller and Noble, *Proc. Soc. Exp. Biol. and Med.*, XIII., 93, 1916.

10 Winslow, Miller and Noble, *Proc. Soc. Exp. Biol. and Med.*, XIII., 1916.

11 Miller and Noble, "The Effects of Exposure to Cold Upon Experimental Infection of the Respiratory Tract." Not yet published.

12 Chodounsky, "Erkaltung und Erkältungskrankheiten," Wien, 1907.

13 Huntington, "Civilization and Climate," New Haven, 1915.

Connecticut, as determined by their monthly wages for piece work, over a period of four years. He found that the annual course of production was as follows: Low at the beginning of the calendar year, it fell still lower and reached its minimum at about the end of January; through the spring there was a gradual increase in output until June; then a moderate decrease until the end of July; in the autumn an increase to the maximum in November; and then the winter descent to the succeeding January minimum. Production was thus greatest in the spring and the autumn, and least in the winter and the summer. A very similar course was followed by the workers engaged in making electrical apparatus in Pittsburgh; and similar confirmation of the validity of the conclusions, with changes in details, was made by the output of other industrial workers in the southern states and by strength-tests of school children in Denmark. All these data combine to demonstrate that the greatest physical efficiency of the individual is found not during the summer or the winter, but at intermediate seasons. That the same is true also of mental activity is shown by a study of the marks secured by the students at West Point and Annapolis in certain classes, especially mathematics. Of the various climatic features of the different seasons that might be responsible for these seasonal differences in achievement, temperature appears to be the most important. Both physical and mental activity seem to be greatest and most effective, not when extreme summer's heat or extreme winter's cold prevails, but when the body is subjected to an intermediate temperature. After a careful consideration of his many figures Huntington came to the conclusion that the optimum temperature of the outside air for the physical work of human beings is about 60° F. (15.6° C.) and for the mental work about 40° F. (4.4° C.) the greatest total efficiency of the human body culminating at the intermediate point of 50° F. (10° C.).

We have thus seen that the body reacts to changes in atmospheric conditions in manifold ways. The most potent of the atmospheric agencies is undoubtedly temperature, but high temperatures exert greater effects when they are accompanied by high humidity. I have said little of the movement of air, but it should be understood that movement is an important agency, and its share in the physiological phenomena has been studied by the New York Commission. By way of general summary it may be said that when an existing external temperature is fairly comfortable to the individual an elevation of it, especially when such elevation is accompanied by an increase of humidity, is deleterious, and the deleterious effects are more pronounced when the air is stagnant. Deleterious effects resulting from such a combination of atmospheric conditions may be in some degree obviated if the air next the skin be put into motion, but a more effective antidote is a reduction in the temperature of the air, and this may be assisted by a reduction in its humidity. All experimentation and observation go to demonstrate that a moderately cool and moderately dry air in motion constitutes the most physiologically helpful aerial envelope of the body. The customary figure of 70° F. (approximately 21° C.) for the atmosphere in which most persons engage in the ordinary occupations of the living room of a dwelling is too high; a range from 65° to 68° F. (approximately 18°–20° C.) with not over 50 per cent. relative humidity, is undoubtedly better, but even such temperatures are too high when much physical activity occurs. Depending on activity and on more obscure corporeal conditions the same external temperature may feel at one time warm and at another time cold. The degree of comfort that is felt—which should not be allowed too potent an influence in deciding what one's environmental conditions shall be—depends, moreover, largely on the thickness of the clothing and on habit. It is surprising how readily one's habits in this respect may be altered. Uniformity in conditions should be avoided; too long a continuance of an existing temperature is dulling to the body; there should be not infrequent and marked changes. Artificial ventilating systems should not necessarily be condemned, but should be operated intelligently and may advantageously be combined with window ventilation.

In these days we hear much of "fresh" air and its merits. We have fresh-air funds, fresh-air schools, and fresh-air babies. All are commendable; but while giving to our funds, opening our schools, and putting our babies out of doors, let us clearly understand what constitutes fresh air. The freshness of so-called "fresh" air lies, not in more oxygen, less carbon dioxide, less organic matter of respiratory origin, and the hypothetical presence of a hypothetically stimulating ozone, but rather in a low temperature, a low humidity, and motion. So far as fresh air itself is concerned, there seems to be nothing more mysterious about it than this.

To what extent ought fresh air to be used as a therapeutic agent? Here intelligent experience, and not opinion without experience, is the only guide. That a physician, indeed, should have any article in his creed of therapeutics that is not based on the intelligent experience of somebody is not to be supposed. It can not be denied that where intelligent experience has been applied to the topic of fresh air as a therapeutic agent the use of fresh air has been almost invariably extended. But no one has a right to maintain, therefore, that it is a panacea. Only when it has been tested in a great variety of pathological conditions—and this can be done with entire safety to the patient—will the therapeutic use and limitations of this physiologically significant agent become known.

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THE ORIGIN OF THE PRE-COLUMBIAN CIVILIZATION OF AMERICA

In the whole range of ethnological discussion perhaps no theme has evoked livelier controversies and excited more widespread interest than the problems involved in the mysteries of the wonderful civilization that revealed itself to the astonished Spaniards on their first arrival in America.

During the last century, which can be regarded as covering the whole period of scientific investigation in anthropology, the opinions of those who have devoted attention to such enquiries have undergone the strangest fluctuations. If one delves into the anthropological journals of forty or fifty years ago they will be found to abound in careful studies on the part of many of the leading ethnologists of the time, demonstrating, apparently in a convincing and unquestionable manner, the spread of curious customs or beliefs from the Old World to the New. Then an element of doubt began to creep into the attitude of many ethnologists, which gradually stiffened until it set into the rigid dogma—there is no other term for it—that as the result of "the similarity of the working of the human mind" similar needs and like circumstances will lead various isolated groups of men in a similar phase of culture independently one of the other to invent similar arts and crafts, and to evolve identical beliefs. The modern generation of ethnologists has thoughtlessly seized hold of this creed and used it as a soporific drug against the need for mental exertion. For