must assume to be pure air) does not enter warmer than the contained air one half of the time and probably not more than one quarter of the time. Mr. Leeds goes on to advocate an open fire and further states—"I believe it would be at all times and under all circumstances very desirable to have a large amount of the air drawn from the floor as nearly as possible under or near each member's seat, and also from under the seats of all the benches in the galleries, but to know how or when and how much to draw from the ceiling would be a much more difficult question to decide. That there should be such openings we know from everyday experience, the necessity for opening doors or lowering external windows to relieve the upper part of a room when it gets too warm. The openings at or near the ceilings require to be closed or opened according to the varying conditions of the room. Heat applied within any building causes movements of the air with more or less force according to the difference of temperature of the external and internal atmosphere. The external wind is a source of considerable power. It is important in the application of power, either to make it conform to and cooperate with the natural forces and merely assist their action, or otherwise make it of sufficient power to entirely overcome all these natural forces—if much care is not exercised in the adjustment of these forces one just counterbalances the other and stagnation is the result. Scientific and medical authorities generally concur in the opinion that in-door air after heating should contain nearly the same proportion of moisture as the average of out-door air of the same temperature, but when air is brought in from out of doors at a temperature of zero and raised by heaters to 68°, it would require the addition of 4.343 grains of water per cubic foot of air to bring it up to the required degree of moisture. For the proper moistening then of fresh, warmed air introduced at the rate of 20 cubic feet a minute for each one of three hundred persons two hours, the air taken at zero and at an average degree of moisture, no less than fifty-nine gallons of water would be required to be added. Exactly how much vapor or what per cent. of moisture is the most healthy has not yet been determined. From much observation we have taken 65 per cent. of saturation as the amount most likely to prove healthy—the mean relative humidity of the air at Philadelphia for the year 1863 was 57.2, and the mean average for twelve years, 68.5.

Dr. Wetherill in his report on ventilation of the Capitôl at Washington says: "Hood, ("Warming and Ventilation,") estimates the air required for ventilation by the amount needed to take up the moisture from the skin and lungs. The air required for respiration (*i. e.* oxidation) is very much less than that needed to hold in solution the vapor of the skin and lungs, which evolve 12 grains of water per minute.

If the temperature of a room be at 60° with a dew point of 45°, a cubic foot of air will absorb 2¼ grains of vapor, or, in other words, the perspiration from the body will saturate 5¼ cubic feet of air per minute. If, however, we take the dew point lower, say not to exceed 20° or 24°, then 3¼ cubic feet of air per minute will be required to carry off the insensible perspiration, while, for the pulmonary supply one-fourth of a cubic foot will be needed, making a total of 4 cubic feet. In summer, as the dew point is higher, more air will be needed, viz., 5 cubic feet per minute for summer ventilation. In a foot note to the above it is stated that Seguin gives the exhalation of water from the lungs, 7 grains, from the skin, 11 grains, total grains, 18 per minute. If the dew point is maintained uniformly at 52° the following is the calculation of quantity exact for this case: A cubic foot of air at a temperature of 65° with the dew point at 52° will absorb 2½ grains of vapor, and if we take the mean of the two authorities above cited regarding the quantity exhaled by each person, we will have 15 grains per minute, and to absorb this under the above conditions will require 6 cubic feet of air. Add to this the one-fourth cubic foot required for breathing, and we have 6¼ cubic feet as the total amount vitiated per minute. The surface of an average man is about 18 square feet. If, therefore, we imagine such a man walking in the pure open air at the rate of two miles an hour on a perfectly calm day the air will be flowing past him at the rate of 176 feet per minute, and as he is one foot deep from front to back, the average thickness of the envelope of vitiated air which surrounds him may be found as follows:

Let A = The quantity of vitiated air per minute in cubic feet.. 6¼
B = The surface of the person in square feet.................. 18
C = The extent of the person in direction of the current of air in feet.. 1
D = The velocity of the current in feet per minute............ 176
x = Thickness of envelope in inches

Then
$$\frac{12\,A\,C}{B\,D} = x$$
and x = 0.018 or 1/55 of an inch.

In supplying air for the upward ventilation of a hall containing an assemblage of people, however, it is absolutely essential that the direction of the current should be vertical, otherwise that which has been vitiated by one person would be given to another to breathe and perspire into. If we now assume a man standing upright of the average height of 5' 6", and the velocity of the current at 5 feet per minute, we will have for the value of the terms in above formula: A = 6¼; B = 18; C = 5⅓ D = 5; whereupon x = 4.16 inches.

If this envelope of 4" thickness be drawn upward, it is clear that the nose and mouth will be always supplied entirely with vitiated air, no matter how pure it may be one foot away, while if it is drawn downward those organs will always be supplied with perfectly pure air. This consideration alone is quite sufficient to determine in favor of downward direction; there are, however, some other advantages in the downward over the upward direction. The temperature of the human body varies 2° either way from 98°, a sudden variation of 5° or 6° being said to be fatal. If, therefore, the air is supplied at a temperature of 65°, it will be 32° cooler than the body. With a downward current the head will be in this cool air while the feet will be inclosed in an atmosphere nearly if not quite as warm as the blood within them, and to "keep the head cool and the feet warm" is one of the fundamental rules of hygiene as well as of comfort.

A current of air coming up through the floor will always bring along with it the fine dust which the greatest care cannot prevent accumulating there to an extent which renders it unpleasantly sensible in all assemblages supplied with an upward ventilation. With the downward ventilation it is only necessary that the dust shall be thoroughly removed from the inflowing air at the mouth of the inlet duct to maintain the hall perfectly free from dust.

Again, with upward ventilation the entire hall is filled with vitiated air, the vitiation having taken place near the point of admission, while with the downward ventilation the ventilation takes place near the point of exit and the whole upper part is full of pure air. In a hall say, 36 feet from floor to ceiling, and the fresh air is admitted through apertures well distributed in the ceiling—it has thirty feet to move before it comes in contact with the heads of persons on the floor. During this movement all eddying currents induced by the increased velocity with which it is necessary that it shall pass through the apertures have become quiet, and the whole mass descends with an uniformity impossible to obtain in the vicinity of persons ventilated with upward ventilation, and one of the most important considerations to be kept in view in ventilating an apartment is to avoid perceptible draughts. Mr. Goldsworthy Gurney, in his examination before a Committee of House of Lords, said: "We have found the down current always more agreeable; the up current is sometimes used, but it is not so pleasing and not so effectual."

One objection used against the downward system is that it is against nature to force air downward. Although this opinion is entertained by an extremely large number of otherwise well-informed persons, every engineer of ordinary attainments knows perfectly well that it is as easy to force air in one direction as another. Another objection is, that as air is additionally warmed at the same time it is vitiated, that which is vitiated and warmed has a tendency to rise whatever may be the direction of the general mass surrounding it. This is true, but this tendency is so feeble that its opposition to a current of 5 feet per minute would not be perceptible. It has been shown that with a vertical current of 5 feet per minute the mean thickness of the envelope of vitiated air surrounding a man of the average size when standing is 4", this more than two hundred times as thick as when he is walking at the rate of 2 miles an hour in a perfect calm. As, however, the air has to be brought from such a direction that mouth and nose are always supplied with air of absolute purity, to insure the control of its direction by mechanical means, a current of 5 feet per minute has been assumed for the minimum velocity to be given.

When the weather is fine, or in other words, when the outer air from which the supply is derived is in the desired condition as regard temperature and moisture, and no expenditure is required upon its conditions, then a maximum amount may be given, the minimum being employed when its condition as regards temperature and moisture has to be changed to the greatest extent. The only limit to the amount of air it will be advantageous to supply is that fixed by the rule that the currents past the person must not be sufficiently rapid to become sensible.

Some persons are sensible to currents of much less velocity than required to render others conscious of them. Most people can feel a current having a velocity of 150 feet per minute, very few can perceive one of 90 feet per minute. To be quite sure that no one, however delicate, should be conscious of being in a current, the maximum current would be safe at 50 feet per minute. But 10 feet per minute will give a bountiful fresh ventilation. The average thickness of the vitiated envelope will then be two inches, or one hundred times thicker than when walking out doors in a calm. With downward ventilation, however, the nostrils are in pure air equally as when walking, the vitiated air enveloping the lower part of the person only, leaving him unconscious of its presence.

Even when the weather is good and the temperature of the air delightful and the wind blowing with the most desirable force, an open window in the side of a great hall filled with an assemblage of people would furnish air to those furthest from the window filled with emanations of all the persons it has passed on its way.

That the air as vitiated has a tendency to rise has been a favorite theory among scientific men. Mr. Gurney was one of the first to stoutly deny the fact in his testimony before Committees of Parliament; he asserted that the downward propulsion which the breath received by the position and direction of the nostrils did not cease so far as the impurities with which it is laden are concerned, till it deposited them on the ground, also that on a frosty day the vapor from a person's mouth may be seen to describe a parabolic curve to the ground. But any one may see