with the number of observations made,— when the observer is quite untrained; while good previous mental training in things more or less analogous to those tested by the experiment might enable the observer to utilize promptly the practice being got in the experiment itself, and so might for a time overbalance the effect of fatigue? Thus, in the present case, the deviation increased most with the child A. L. B. and one other person, and decreased most with the artist L. F. and one other, but the data are too few to be more than suggestive. It would seem that further experiments upon the relation of fatigue, and of the effective practice got during each experiment, to previous training, etc., might be quite varied in direction and have some educational interest; the best training, *cœteris paribus*, being presumably that which best enables the trained to utilize fresh opportunities for training of a kind somewhat new to him.

2. Tho probable error of an estimated distance is, of course, some function of the distance and of other data; but *what* function of the distance, when the other data remain, as far as may be, constant? May it not be commonly taken as some low power of the distance whose exponent increases slowly with the distance? In the present case the ratio of the two distances tried is 4.37 : 1; and the average odserver's mean deviation in inches from the truth, and from his own average estimate, respectively, are 2.69 and 2 56 times greater for the long distance than for the short; so that the exponent here would not be far from $\frac{2}{3}$.

J. E. OLIVER.

Ithaca, N.Y., March 5.

Work and its Relation to Gaseous Compression and Expansion.

IT is quite well known that the fundamental, and perhaps the most important hypothesis in theoretical meteorology is this, that work is done by air in expanding, and that heat is evolved whenever air is compressed. See "Recent Advances in Meteorology," p. 41. There is a most serious fallacy in this theory, however, in that it ignores the resistance against which the air expands, and considers that the mere diminution of the distance of the molecules of a gas, without the direct expenditure of external energy in changing this distance, can evolve heat.

An illustration will serve to make this clear. Take a cylinder one square foot in area and two feet high with a piston at the top and the air beneath it at atmospheric pressure. Place weights, pound by pound upon the piston, allowing all the heat developed to escape into the outside air. When we have added 2,160 pounds, the air beneath will be compressed to two atmospheres. Fasten the piston and its load, and connect the cylinder with another holding one cubic foot and containing air at normal pressure. An equilibrium will be quickly established and the pressure will be at 1.5 atmospheres in each cylinder. The potential energy remains the same as before; no work has been done and therefore there has been no change in temperature, except a slight chilling and heating due to the rush of the air from one into the other.

Return to the cylinder with the air compressed to two atmospheres and having the same temperature as the outside air. Take off the weight from the piston pound by pound, and the air will gradually expand, and in doing so will lift a weight, thereby doing work which cools the air very greatly, about 50° F. if the initial temperature was 60°. Instead of taking off the weight pound by pound, however, suppose the whole 2,160 pounds had been removed instantly. The only resistance which kept the air compressed has been entirely removed, and it is very evident that the air would expand without doing any work, if we consider that the piston moves back slowly; or, in other words, if we neglect the resistance of the air to the rapid motion of the piston, and hence there would be only a very slight chilling, owing to the work of imparting a certain velocity to the particles rushing out. The same result would have been attained if we had fastened the piston and its load, and then had turned a stop-cock, allowing the air to escape into the atmosphere without making a noise.

I am well aware that the ordinary interpretation of this illustration is very different; for example, Tyndall, in his "Heat as a Mode of Motion," p. 64, in a somewhat similar discussion, says: "The gas, in this experiment, executes work. In expanding it has to overcome the downward pressure of the atmosphere, which amounts to 15 pounds on every square inch, and also the weight on the piston itself. It is just the same as what it would accomplish if the air in the upper part of the cylinder were entirely abolished, and the piston had a weight of 4,320 pounds." I do not see that this changes the aspect of the case at all. Suppose that the air were compressed to two atmospheres beneath the piston, and that that was loaded with 4,320 pounds, while a perfect vacuum existed in the upper part of the cylinder, suppose that we suddenly remove 2,160 pounds from the piston. The piston, still having a load of 2,160 pounds, would fly to the top of the cylinder. How much work has the air done in expanding from two atmospheres to one? None at all. It looks very much as though the compressed air must have lifted that weight, but a little reflection will show that this is not the case. The best way to understand it, perhaps, would be to think of the weight after it reached within .001 of an inch of the top of the cylinder. Here is a weight of 2,160 pounds with the air under it at atmospheric pressure; in one sense the air sustains the weight, but if the air at atmospheric pressure sustains the weight at this point (the top of the cylinder), then the air at the same pressure would have sustained it at the middle of the cylinder. In other words, if we had allowed the compressed air to escape when the piston was at the centre of the cylinder, still with its load of 2,160 pounds and with a perfect vacuum above, there would have been an equilibrium, and we could have pushed the weight up and down, allowing it to stand at any point so long as the outside air had a communication with the lower side of the piston. Does not all this show that the compressed air, considered by itself, did not support any part of the weight at the middle of the cylinder, but was free to expand without lifting any weight or doing any work?

We are strictly taught that the old idea, "nature abhors a vacuum," is not at all tenable; but if we lay aside strict analysis for a moment and resort to this view, I think it will make the situation plainer to us. To all intents and purposes, when our piston loaded with 2,160 pounds had a perfect vacuum above it, we may say that it was sustained by that vacuum, or, at least, that the compressed air had nothing to do in supporting it or in moving it to the top of the vacuum. This seems to be quite an intricate problem, but a little reflection will show that the piston loaded to 2,160 pounds, and having a perfect vacuum above it, with air having free access to its under side, is in precisely the condition it would be in if both ends of the cylinder were open to the air and the piston without weight were located at any point in the cylinder. In this case the piston may be pushed up and down without meeting any resistance except that to the flow of the air.

Consider now the question of heated air rising in the atmosphere. We may simplify the problem slightly by taking a balloon, having an infinitely flexible envelope and without weight. Empty the balloon, and tie the neck so that no air can enter. It would require a pull of 15 pounds to the square inch to separate the sides of the balloon, owing to the pressure of the air. Incredible as it may seem, this is the force which theoretical meteorology has introduced into every discussion of the dynamical heating and cooling of the air, and of the cooling and heating of masses of air as they ascend or descend in the atmosphere,—a force which it is no exaggeration to say is at least 25,000 times as great as that really exerted or developed. Inflate the balloon one-third full with hydrogen gas. The work required to do this is that needed to displace a volume of air equal to the volume of gas which enters the balloon, or it would be that of lifting a weight equal to 1.2 ounces per cubic foot half the height of the balloon. It will probably be said that the outside air helps in this inflation, and I grant that for argument's sake.

Let the neck of the balloon remain open to the outside air, and suppose that the gas can just lift a weight attached to the balloon. The balloon will rise in the atmosphere to a point where the pressure is 10″, or until the gas has expanded to fill the whole envelope. Since the work of the balloon is open to the air, the pressure inside will continue exactly the same as that outside. A little reflection will show, however, that the conditions would be precisely the same whether the neck was opened or closed. The only work the gas would do in expanding would be that which it did in inflating the balloon, or it would simply displace a volume of gas equal to the enlarged volume of the balloon. It is easy to see that this work would be almost inappreciable.

It may help to clearness if we consider two balloons suspended by an endless rope passing over a pulley situated at the extreme height to which the balloon rises. This rope has no weight, and there is no friction at the pulley. One of the balloons is at the earth's surface, and the other at the highest point. The system is in equilibrium, and it would require but the slightest weight at the topmost balloon or a diminution of weight in the balloon at sea-level to disturb the equilibrium and cause the balloons to change places. It is very evident that throughout this motion the air sustains both balloons, and the work of expansion in one balloon or the work done by the air in compressing the gas in the other balloon would be almost inappreciable.

Instead of using hydrogen in our balloons we may use heated air and the results of the analysis would be exactly the same. Lastly, we may dispense with our envelope, and simply consider the heated air as rising in the atmosphere. As we have just seen, this air would do very little work, and the consequent cooling would be very slight; the converse would also be true, that the work of diminishing the distance between the molecules of the gas would be very slight, and the heating almost inappreciable so far as the compression was concerned.

The application of these views, if they shall be sustained, to nearly all theories in meteorology is very obvious. It has been only after the most careful study and analysis of all the questions involved, and a taking up and explaining all the apparent contradictions between the older views and these, that I have felt justified in presenting them so much in detail. I bespeak for them a most searching examination and criticism, hoping that thereby the whole truth may be established. H. A. HAZEN.

March 2.

Pyrite Incrustations of the Cretaceous Formations of Middlesex County, N.J.

ONE would scarcely expect to find beautiful mineralogical specimens in so uninviting a place as a clay pit. The specimens of pyrite incrusting wood and bark, that may be found in most of the clay pits of Middlesex County, N.J., are very beautiful, whether viewed æsthetically or as cabinet specimens. The incrustations as found near Ford's Corners occur in the black and dark-colored clays which usually overlie the lighter and better clays. This dark stratum of clay contains many remains of leaves, twigs, and bark, which have been partially changed into brown coal. Occasionally whole trunks are found which yield wood which may be wrought into a variety of ornamental objects which are capable of taking a good polish. As waters containing sulphates of iron come in contact with this carbonaceous matter the carbon unites with the oxygen of the sulphates and sulphide of iron is left in its place. In some specimens the pyrite is found covering the carbon, while in others the carbon has been completely replaced by pyrite; at the same time the form of the wood is perfectly retained.

Specimens having the form of twigs not thicker than a lead pencil, and having a fine crystalline surface, are occasionally found. These make very pretty breast-pins when suitably mounted. Some specimens look as though the material of which they were formed had been poured out whilst hot, and had spread on cooling much as hot lead does when poured out on a flat plate. Many specimens occur in the shape of balls as large as hen's eggs. These are made up of concentric layers of scale-like crystals formed about a nucleus at the centre. As these are exposed to the weather they scale off gradually, sometimes remaining bright until the balls disappear completely, while at other times they turn dark immediately.

The pyrite weathers very quickly when left exposed to the action of the air, and the clay waters. If, however, the specimens are collected and washed as soon as they are removed from their native beds, they will remain bright indefinitely.

Specimens are occasionally found weighing four or five pounds. When the pyrite is exposed to the weather in contact with sand or gravel, as the iron is changed to the ferric oxide it cements sand and gravel together so that very often the resulting conglomerate retains the form of the original lump of wood. Your clay-pitter does not look with a favorable eye on the "sulphur balls," as he calls them, for clay containing much sulphide of iron is worthless for brick-making.

Of late years large amounts of clay containing iron have been used for making the so called mottled bricks.

D. T. MARSHALL.

Metuchen, N.J., March 2.

AMONG THE PUBLISHERS.

THE American girl is not slow to grasp a chance. Some time ago *The Ladies' Home Journal* organized a free education system for girls, and the magazine is now educating some forty odd girls at Vassar and Wellesley Colleges, and at the Boston Conservatory of Music, all the expenses of the girls being paid by the *Journal.*

— The March number of *Babyhood* contains an article on "Getting the Teeth — First and Second," by the medical editor, Dr. L. M. Yale, which corrects certain misapprehensions as to the teething process and the troubles which are popularly supposed to accompany it. Similarly helpful medical articles are "The Care of Delicate Children," by Dr. H. D. Chapin, and "Cuts and Scratches," by Dr. H. Power. An alleged "sure cure" for diphtheria is also discussed by a competent writer. Of most general interest, perhaps, is a curious article on "What Shall be Done with Him?" — an account of a completely unmanageable though not at all vicious boy, which is sure to give rise to considerable discussion.

— We have received a copy of the American edition of "Longmans's New School Atlas," the joint work of George G. Chisholm of the Royal Geographical Society and C. H. Leete of the American Geographical Society. It contains thirty-eight double-page maps; but in many cases what is numbered as a single map is really a collection of two or three maps. The introductory maps illustrate the various physical and astronomical phenomena of the globe, the climates and vegetation of different regions and the distribution of races and religions, while the remainder of the book is mainly devoted to political geography. There are, however, several special maps illustrating the climate, geology, and industry of the United States and Canada, and one showing the several acquisitions of territory by the United States. Most of the maps are so colored as to show the elevation of the different sections of land above the level of the sea; which seems to us to be making too much of a very small matter. The selection of maps is very judicious, and the United States does not appear with such overweening importance as it does in most American atlases; though it receives as much attention as the British Empire, and much more than any other part of the world. The number of towns indicated on most of the maps is small; and though a school atlas ought not to be overburdened with town names, the present work would have been better if it had contained more of them. The maps are well engraved on excellent paper, and as a general atlas of the world for school use, the book is meritorious. It is published by Longmans, Green, & Co. of New York, at one dollar and a half.

— Professor David Starr Jordan makes the inspiring influence of a great teacher of science strongly felt in the account of "Agassiz at Penikese," with which he is to open the April *Popular Science Monthly.* The article contains many of Agassiz's own words, which reveal the master's spirit better than pages of description. An authentic account of what treatment the Catholic Church actually gave to Galileo and his discoveries and writings will be given by Dr. Andrew D. White in one of his Warfare of Science papers. Attempts have been made to disprove or explain away much of this ecclesiastical persecution, but Dr. White's statements are fortified by copious citations from authors of unquestioned orthodoxy. The same article tells just how far into