of arts, has heretofore been conferred upon its graduates.

At Smith College Harriet W. Bigelow has been promoted to be professor of astronomy, and Frances Grace Smith to be associate professor of botany.

At Yale University Dr. Alexander Petrunkevitch has been promoted to be assistant professor of zoology, and Dr. Carl Johns, to be assistant professor of chemistry.

DISCUSSION AND CORRESPONDENCE

THE AIR WE BREATHE

To the Editor of Science: As a member of the American Society of Heating and Ventilating Engineers, who had the pleasure of hearing the recent address of Dr. Gulick before that society, I desire to reply to his letter in Science of March 3. I believe that Dr. Gulick is engaged in a research whose results may be of the utmost importance to the health of a large fraction of the human race—namely, the children in the schools—and it is to be desired that he be given every encouragement to continue in it.

First, to answer some of his questions in regard to the physics of atmospheric air. No one knows "the reason why" raising the temperature of air increases its capacity for holding moisture. It is merely one of the great facts of nature, like gravitation, and like the fact that water freezes at 32° F. At 32° F. a cubic foot of air has the capacity of holding in a gaseous condition 0.0003 pound of water; at 62°, 0.00087 pound, at 72°, 0.00121 pound, at 102°, 0.003 pound, and so on.

"Is there any difference between steam and humidity?" Steam is water in a gaseous state. There is no difference between steam and the gaseous or uncondensed vapor of water in the atmosphere. When steam escapes from a pipe into an atmosphere colder than itself it condenses into fog, which is visible, but if the atmosphere is not saturated with moisture it will rapidly dry the fog, turning it again into invisible vapor. Humidity is the condition of the atmosphere as regards moisture. Relative humidity is the ratio or percentage that the moisture contained in the atmosphere bears to the maximum quantity it can contain at the same temperature. Thus if a cubic foot of air at 62° contains 0.00087 pound of water vapor, the air is "saturated" and the relative humidity is 100 per cent., but if the same quantity of moisture is contained in a cubic foot of air at 72° the relative humidity is only $0.00087 \div 0.00121$ or 72 per cent.

"The manuals of the heating and ventilating engineers tell us that with a good system of ventilation the opening of windows causes only danger; yet as a matter of fact, children in rooms so treated do not exhibit the distressing conditions," etc.

The "danger" from opening windows is not to the children in the room in which the windows are opened, but to the children in the adjoining rooms in which the windows are not opened. In the fan-blower or "plenum" system of ventilation the entrance and exit flues and dampers are so designed and adjusted as to cause each room to receive its due proportion of the total air supply. If a window is opened in one room (unless the wind is blowing towards the window) the resistance to the passage of air from the room will be less than if only the exit flue were open; consequently there will be a lower static pressure in this room than in the other rooms, and it will receive from the entrance flue more than its proper share, thus robbing one or more of the other rooms of their share. The flow of air in a complex system of piping is like the flow of water. If in an apartment house with ordinary plumbing a tenant on a lower floor draws hot water into a bath tub, he will rob the bath room on the floor above of its hot water supply for the time being. So in a school-house fitted with air pipes, if the flow of air from the fan into one room is increased by opening a window, there will be a smaller supply for the other rooms. The "danger" therefore is that of unbalancing the ventilating system. This danger would be avoided if there were in use an automatic arrangement for closing the damper of the admission flue every time a window was opened.

The science of heating and ventilation may be divided into two branches: (1) hygiene, (2) engineering. The first includes the knowledge of the effect upon health and physical and mental vigor of the condition of the air in buildings as regards temperature, relative humidity, content of CO_2 and other noxious gases, etc. The second includes the knowledge of how to design, install and operate apparatus which will maintain the conditions that are desired. The engineering branch of the science is in fairly good shape. If the temperature, humidity and CO_2 desired in a given school room are specified, the engineers can furnish apparatus which will meet the specifications, and whether or not the specifications are fulfilled can be tested by means of thermometers, hygrometers and analyses of the air in the rooms. The hygienic branch, however, is in a very poor shape. It is for the doctors to settle, and not for the engineers.

In Dr. Gulick's address he threw doubts "upon the very foundations upon which the science of heating and ventilation is built," that is, the hygienic foundations. He doubts, I understand, if it is necessary to supply sufficient air to keep the CO_2 down to 8 parts in 10,000, the recognized standard. All that the engineers know is that there is a tradition, handed down in the text-books from time immemorial, that the CO_2 should not exceed this limit, and on the generally accepted statements that a man will exhale on the average 0.6 cubic foot of CO_2 per hour, and that the outside air contains about 4 parts in 10,000, the requirement will be met by furnishing 1,500 cubic feet of air per hour to each inmate. To be on the safe side, the school authorities in Massachusetts many years ago, placed in their code the specification that 1,800 cubic feet per hour should be supplied for each pupil, and this requirement has been placed in the statute laws of several states.

As to the desired temperature and humidity, and as to the desirability of having artificial ventilation at all, the doctors disagree. Dr. Gulick's letter states that Doctors Thompson and Brennan "think we ought to do away all systems of ventilation, and use simply natural ventilation—open windows," while Dr. Leonard Hill has found an "admirable result" from a plenum system, giving a moving air at 57–60° F. and about 70 per cent. relative humidity with all windows and doors kept closed. Both of these ideas are opposed to the modern American system, which is a plenum system maintaining a temperature of 70° F., letting the humidity be what it may, with no attempt to control it. A relative humidity of 70 per cent. at 60° F. is about equivalent in actual quantity of moisture to 50 per cent. at 70° F., and this is probably much greater than the humidity in New York schools in clear cold weather.

The temperature that is desirable in school rooms is probably largely a matter of habit and local custom. Our people are accustomed to a room temperature of 68–72°, and think they like it. Englishmen in their own country profess to like 58–62°. Which is actually the best temperature, or whether the higher temperature is better here and the lower in England probably no one knows. As to the effect of humidity at temperatures between 58° and 72° F. does any one really know? We do know that high humidity at 80° is much more uncomfortable than low humidity at 90°, and we know also that regions of low humidity are famous as health resorts.

There is a vast amount of ignorance as to the hygiene of ventilation. Dr. Gulick seems to have an arsenal of facts (?) and a body of "as yet undigested information" on the subject, and it is to be hoped that he will correlate and digest them, and present them in digested form before some learned society and have them discussed and printed for the public benefit. I venture the opinion, however, that all the investigations by the authorities he names, after being correlated and digested, are insufficient in extent and not sufficiently scientific in quality to form the basis of a final judgment on the disputed questions in the hygiene of ventilation.

What is needed is a new research, aided by all the facilities of modern science and instruments, under the auspices of the Carnegie Institution or the Russell Sage Foundation, to discover by direct experiment on a large scale, the effect upon the health and comfort of school children, of the three different systems of ventilation: (A) Open windows, as recommended by Doctors Thompson and Brennan, (B) the plenum system recommended by Dr. Hill, with low temperature and high humidity, (C) the American plenum system with 70° temperature and low humidity.

For the carrying out of a portion of the research, I suggest that experiments be made in several rooms of a large grammar school, all with the same window exposure and light, one room being treated by direct radiation and all ventilation obtained by open windows, and others by the plenum system, with the volume, temperature and humidity regulated at will. Let the rooms be thoroughly aired, say from 8 to 8.30 A.M., then when the children enter at 9 A.M. have their condition noted by trained specialists, with all the known pathologic and psychopathic tests, including the use of instruments for recording the pulse and the respiration, "reaction time," etc., and let these tests be repeated at noon. Tests should also be made to determine relative mental fatigue, lack of attention, etc. Statistics should be collected to determine what relation, if any, exists between the ventilating system or quality and quantity of ventilation in the schools and the prevalence of adenoids, sore-throat, headache, colds, etc. It may be found that these troubles have relation to the environment of the child during the nineteen hours that he is out of school rather than the five hours that he is in school.

Experiments should be made to find whether the percentage of CO_2 in the school room has the relation to the child's health or mental vigor that it has been commonly supposed to have, and whether an air supply of 600 or 1,200 cubic feet per hour per pupil, instead of 1,800, produces any bad effects. Bacterial examination of the air should be made at the same time.

Such a research as is suggested will take a long time and will cost much money, but is there any investigation now under way that is more worth the money, or that promises more for the welfare of the race?

William Kent

To the Editor of Science: I am writing in the endeavor to clear up some of the elementary questions asked by Dr. Luther H. Gulick in his letter "The Air We Breathe," published in Science of March 3.

When air is completely saturated with water vapor, the humidity in it is vapor, that is, a gas at point of condensation. At other times humidity is a gas, just as much so as CO_2, it is in fact superheated steam in the air. A gas just ready to condense to liquid is called vapor; thus, ordinary steam is a vapor, while superheated steam is a gas, obeying all the well-known gas laws. Humidity is a vapor whenever the air is completely saturated, being then the same as ordinary steam in the air; when, as is usually the case, air is unsaturated, then humidity is superheated steam in the air—a gas. Heat added to vapor superheats it, that is, raises its temperature. Heat taken from vapor condenses some of the vapor to liquid without altering the temperature.

Liquids remain in the liquid state only by virtue of external pressure exerted upon them, and any liquid will quickly turn to gas if all external pressure (which is usually that exerted by the atmosphere) is removed; the tendency for a liquid to gasify depends upon the temperature and kind of liquid, and nothing else.

If a closed vessel containing water and air is let stand at any temperature until conditions have become constant the air will gradually become saturated with water vapor, and the amount of water vapor that will be thus absorbed by a given volume of air will depend only on the temperature of the air; it would, moreover, practically be not only independent of the pressure of the air, but would be the same if another gas or even a vacuum were substituted for the air; also the pressure exerted by the water vapor filling the given space at a given temperature would be the same in all these instances.

In a gas mixture the total pressure exerted by the mixture upon the walls of a containing vessel is the sum of the pressures exerted by the individual gases composing the mixture; thus, air is a mixture of oxygen, nitrogen, CO_2, superheated water vapor and many other so-called rare gases, and the atmospheric pressure is the sum of all the pressures exerted individually by all these gases.

Take again the closed vessel containing water and air; the quantity of water vapor per cubic foot of space above the water, as well as the pressure exerted by this water-vapor, conditions having become constant, will always be the same for the same temperature, but will rapidly increase with rise of temperature. The following tabulation shows the maximum capacity of air (or other gas or better simply of space) for water vapor at different temperatures, and also the pressures exerted by the water vapor at these maximum capacities, the values being taken directly from the steam tables of Marks & Davis, Table I.

Temperature °Fa	Max. Capacity Lbs./Cu. Ft. Space	Vapor Pressure Lbs./Sq. In.
32	.000304	.0886
40	.000410	.1217
50	.000587	.1780
60	.000828	.2562
65	.000977	.3054
70	.001148	.3626
75	.001346	.4288
80	.001570	.505
85	.001832	.594
90	.002131	.696
95	.002469	.813

To obtain grains/cu.ft. multiply lbs./cu.ft. by 7,000.

The extent to which what Dr. Gulick calls the "thirst" of air for more water vapor is unsatisfied is the difference between the maximum capacity and the quantity actually present. The rapidity with which moisture is evaporated from a moist surface, such as the skin, probably depends, first, on the "thirst" of the air; second, upon the velocity with which the air moves across the moist surface; and third, upon the physical condition of the moist surface, particularly with respect to temperature. Relative humidity is ratio of the quantity of water vapor actually present to the maximum quantity that could be present at a given temperature. Relative humidity will not of itself determine air "thirst," as this "thirst" will be different for the same relative humidity at different temperatures.

Dr. Gulick asks, "Does any one know why delicate children and tuberculous persons get well out of doors but fail to do so indoors." I am not a physician but do believe the air "thirst" is certainly, as a rule, far greater indoors than out of doors, and that this "thirst" continually absorbs moisture from the skin, tending to keep it cold and dry and chilling it in local spots.

WILLIAM J. CROWELL, JR., CH.E.

TO THE EDITOR OF SCIENCE: The capacity of gases for carrying vapors of volatile liquids and the capacity of various volatile liquids to take the vapor form is a subject to which the writer recently has had occasion to devote considerable thought in connection with certain technical processes. Possibly some of the confusion which it seems exists in Dr. Gulick's mind may be dispelled by the following statements which I think can be readily verified.

I will attempt to answer the questions propounded by Dr. Gulick on page 327 of the March 3, 1910, number of SCIENCE.

1. Water vapor, I believe, is the correct term to be used in a discussion of the hygienic effect of atmospheric humidity since the word steam sometimes conveys the meaning of the cloud of minute water particles resulting from condensation of water vapor in the presence of another gas (air).

2. Water vapor then (the amount of which, compared with the total capable of being carried, in the air at any temperature represents its humidity) does "act strictly in accordance with the ordinary laws governing the movement of gases."

3. Humidity in the air is a term used to express the amount of water vapor in the air usually expressed in terms of the percentage of the total amount capable of being carried at that temperature.

4. Water vapor (as long as it remains in

the vapor form) is a gas and obeys all the laws of gases.

5. Air has only the same capacity for carrying any vapor (water vapor) that any other gas has.

6. The amount of humidity (*i. e.,* the basis for calculating percentage humidity) that air, or any other gas, can carry is not a function of the nature of the gas at all.

7. The amount of any vapor that any gas can carry depends solely upon the nature of the substance vaporized and the temperature.

8. The actual percentage by volume of vapor which any gas (air) can carry, *i. e.,* the saturation point, is determined by the following formula:

$$\text{Per cent.} = \text{Pt./Atm.}$$

Where Pt. = vapor tension of the liquid at temperature *t,* and Atm. = pressure of the atmosphere. The vapor pressure (the force which a substance exerts to take the vapor form) of water and most common liquids is given in physical tables for all ordinary temperatures.

For example, at 20° C. (68° F.) water has a vapor tension of 17.363 millimeters of Hg. Air saturated with water vapor at 20° C., therefore, contains 2.28 per cent. If it only contains 1.14 per cent., its humidity is only 50 per cent. At 0° C. (32° F.) the vapor tension of water is 4.569 mm. and air saturated at 0° C., therefore, carries only .6 per cent. water vapor, or considerably less than if only 50 per cent. saturated at 20° C.

9. Strictly, air is not altered by increase in temperature so that it can carry more water vapor, but the liquid producing the vapor is changed so that it has a greater vapor tension and a proportionately greater percentage of vapor will enter the air.

10. The rate of evaporation then from any given moist surface depends upon the actual amount of water the air is capable of taking up (not on the *percentage* of unsaturation) and upon the relative rapidity of movement of the air.

For example, from a square centimeter of skin surface with saturated air no evaporation can take place at any temperature. At 20° C., however, and 50 per cent. humidity, let us say that 1.14 milligrams are vaporized per minute, then at 0° C. and 50 per cent. humidity only .3 milligram would be vaporized in the same time. Even absolutely dry air at 0° C. evaporates less moisture than at 20° C. and 70 per cent. saturated. This is on the assumption that the skin is equally moist at both temperatures and that there is equal movement or no movement of air in both cases.

The amount of moisture that may be in the air, whether greater or less, can have no physiological effect, for that already there can be considered a dry gas. There need only be considered whether or not conditions are such that much or little or none can be evaporated.

11. Perhaps the normal human organism requires the removal of the heat produced by mental or physical activity at a certain fairly definite rate. In such case both heat carried away by radiation and by evaporation must be considered, one in a measure supplementing the other. Low temperatures increase radiation and decrease heat loss by evaporation and *vice versa.*

For example, one extreme condition would be when the air is saturated with water vapor and at or above the body temperature. The body then has lost all temperature control. At any lower temperature there still remains radiation though the air be saturated.

The other extreme condition would be for extremely low temperatures where, though there is little cooling from evaporation and little moisture produced for evaporation, radiation is excessive and the only remedy is the prevention of radiation by additional clothing.

Fortunately at low temperatures when radiation is high, there is little loss from the latent heat of evaporation because air at low temperatures, even if perfectly dry, can carry away little water vapor. In addition to this balance of effect from outside influences, there is the most important physiological influence of perspiration increasing or decreasing the moisture to be evaporated.

Is it not possible, therefore, that the best physiological condition is that where heat loss by radiation just balances that produced and there is little or no use for perspiration and its evaporation. In other words, is not the physiological process of perspiration exhausting and only necessary because the atmosphere is too hot to permit of removal of heat by radiation without the aid of positive physiological effort?

In Atwater's and Benedict's experiments the data given should show the amount of water eliminated to the air from the breath and through the skin. This represents a definite number of calories absorbed and should show under the conditions the relation of the amount of heat removed by evaporation to that removed by radiation.

These suggestions are made, as you can see, by a novice in hygiene but they may possibly throw a little side light on the problem.

LOUIS CLEVELAND JONES

UNIVERSITY FELLOWSHIPS

TO THE EDITOR OF SCIENCE: In SCIENCE of February 10, just at hand out here, there appears a letter by Dr. S. N. Patten upon which I would like the privilege of commenting.

The letter divides itself into two main contentions.

First, by means of a table of present occupations, an attempt is made to show the prosperity of a group of "fellows," thereby demonstrating the value of fellowships. To prove the point the investigation would have to be conducted along lines similar to those recently followed in another connection by Professors Furman, of Stevens Institute, and Cooley, of Michigan.[1] As it is, the surface indications presented by this table lead—through the legitimate inferences which may be drawn—to a conclusion diametrically opposite to the one there stated.

Of the 183 fellows listed as living and of known occupation, 27 belong to a group comprised of literary workers, social workers, ministers and students. To assume any of these wallowing in a wealth of financial returns offers difficulty to the imagination.

[1] *Proc. Soc. for the Prom. of Eng. Ed.*

The second group, 138, consists of 31 teachers in normal and secondary schools and 107 instructors and professors. Lacking specific knowledge as to these individual cases it is fair to reason that these men are no better off than the average of similar ages in their profession. From a knowledge of the prevailing conditions it would be proper to assume that $1,200 would not be far from the average salary of this group. Under present-day conditions this looks more like "starvation" to me than, perhaps, it does to one who pictures to himself living on an equal salary at the same age, under the conditions of thirty years ago.

This disposes of all save 18 experts and business men. Lacking specific evidence, it is fair to presume that this 10 per cent. is financially more prosperous than the other 90 per cent.

I hope that Professor Patten will complete his table, adding, for instance, the individual ages and salaries. This would give a chance for comparison with an equivalent group of non-fellows; at all events, it would transfer the matter from the realm of speculation to that of hard fact.

But it is the second of Dr. Patten's contentions which interests me more. He lays down the dictum that it is "rapidity of promotion and not lack of it that ruins promising investigators." To sustain this he gives a couple of inconclusive instances. In neither case are the returns, upon which to base final judgment, yet in.

To test his statement I jotted down a list of American scholars whose names occurred to me offhand, for one reason or another. Then I looked up their date of birth and of call to full professorship. The table follows, and the only name on my list omitted below is that of William James, whose call was deferred to his forty-third year because he started out in the field of anatomy and physiology and when he shifted to philosophy had his apprenticeship term as assistant professor to serve all over again.

Does this list bear out the conclusion that an early call or rapidity of promotion is the