The Historical Development of Science

SOME PEOPLE WHO HAVE STUDIED OUR ATMOSPHERE.

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PROVIDED that you have a good knowledge of our present beliefs with regard to the layer of gas surrounding our world, and which we call the atmosphere, it is very interesting to go away back into the past and read about the funny ideas held on the subject by our remote ancestors, and quite profitable to see how we have gradually arrived at the ideas which we have today.

If one does not know rather well what *are* our present views on the subject, then, as we really have not developed so remarkably in intelligence over the last 2,000 years, the ideas held by the ancients may not appear so strange. We know a lot more today because we have at our disposal the accumulated knowledge of our ancestors ; they have speculated as to what everything is all about, and more recently have carried out an enormous number of actual experiments to find out what they wanted to know.

Suppose parents actually became as " fed up " with their children as they say they are after a long holiday dose of them ; suppose that in some such early home condition of " fed-up-ness ", all of them had, at about the charming age of two years old, been dumped on some ideally situated vacant island, with natural cold water laid on in convenient streams, sheltered caves into which they could toddle for protection, and with luscious and readily digestible fruit dropping, when properly ripe, of course, at their feet ; then many of them would have lived and grown up to our present ages—but would only be the slightest bit, perhaps an immeasurably small bit, more intelligent than if the same experiment had been carried out by the Greek mothers and fathers two and a half thousand years ago. We do not " know " today just because we are more capable of knowing, but because other people have tried and failed, or tried and succeeded ; and because what they did, and what they said about what they did is *our* knowledge for the learning.

The existence of what we call the air, as an actual enveloping material, must have been apparent to very early thinkers ; and we know that the Greeks, some 500 years or so B.C., divided everything up into the so-called " elements "—earth, air, fire, and water. From this, everything could be made ; and materials when burnt passed to the air, to fire, and to water. Aristotle gave the element air, or " vapour ", the properties of " wetness and heat, or gaseousness ". The Greek philosopher Plato (427–347 B.C.) went so far as to give a structure to the air, and imagined it built, for reasons known to himself alone, of those geometric solids called regular octahedra ; but it still remained to him an element, and the Greeks carried out no chemical or physical experiments on it, so far as we know; but then they were much more interested in philosophy than in experiment.

Whilst the Greeks were interested in thinking and talking, the Romans who followed them as the cultural leaders and controllers of the world were more interested in doing things; they applied the older knowledge to aid them in engineering and in warfare, but actually never produced a true scientist. Lucretius, who lived about 55 B.C., just when his contemporary Julius Cæsar was invading Britain, discusses observations he has made of thunder and lightning in the atmosphere, and the occasional presence of unpleasant odours and suffocating vapours; but does not give us any scientific observations.

Here we have already in this article passed over the many thousands of years of civilization prior to the Christian era, and all that was observed was that there was an invisible something called, in varied languages, the air. Strange theories were held, practically as superstitions, some of which are still held today; for example, it has been handed down from some unknown early source, so that today it is believed by some tribes of Esquimaux, Northern Americans and villagers of central Europe, that in times of eclipse of the moon or sun the air becomes filled with poison gases, which poison all exposed water and are harmful to crops and to people and their "endeavours". It is suggested that the idea arose from the old mythologies, when eclipses were due to monstrous dragons or other beasts swallowing the sun or moon and thus causing the eclipse; the unpleasant animal bellowed forth poison gas, so these villagers still rush to cover up the wells, and buckets, and in many cases stop everything they are doing, on account of the "unlucky" poison which is coming into the air.

There was nothing more substantial than speculations and yarns such as this until the 17th century; it seems extraordinary, when men were just as capable mentally of finding out things by experiment, and of making machines to use in experiment, and of reasoning on the results of their experiments so as to employ them for fresh work or for application, that they did not do so. The *attitude of mind* was not there, however, and not only were people not encouraged to make discoveries, but they were often actively discouraged.

And now about a thousand years passes from the decline of the Roman Empire, and kings and emperors roam the world and manage to destroy big percentages of the populations without any help from modern science, and there is nothing in the way of investigation into the atmosphere to report until about the beginning of the 17th century.

The term "gas" was probably invented by Jean Baptiste Van Helmont (1577–1644), a physician born in Brussels; he recognized that air-like material, gas, was given off during some chemical actions, but could not devise any means of collecting the gases; that may seem strange to us, but we have been taught.

We know that air has mass; we can weigh it; in the Greek writings (of Aristotle and of Plato) are casual suggestions that the air element has weight, but no one knew anything about it. Neither was it philosophically permissible to have empty space—

Nature was ordered to "abhor a vacuum", and consequently, as no experiments were performed which proved the contrary, people believed that Nature obeyed the order—until the 17th century.

Galileo (1564–1642) was familiar with the ordinary lift pump, and was astounded by and unable to account for the observation, brought to his notice, that water could not be raised by it to a height greater than 30 feet. You would account for it by saying that the pressure of the atmosphere is only equivalent to the pressure at the bottom of a column of water about 30 feet high, so that even if you remove all the air pressure from above a column of water, the external air cannot "balance" a water column more than some 30 feet high. Galileo, though a great scientist, and now a famous man, had not any preconceived ideas on the subject, because no one previously had thought much about it. He was interested in this observation, because knowing nothing much then about universal gravitational attraction, he had a theory that a solid held together because of what he called "the power of the vacuum"—he thought that Nature refused to permit a vacuum, so that if the copper were not there, the air would rush in to take its place, so that the air must really be pushing outside ready to take the place of the copper if it disappeared—that is, he proposed an idea of atmospheric pressure. He also carried out one other experiment for us for this article—he weighed a glass balloon filled with air under ordinary pressure, and then put in a lot more air (thus making a high pressure in the ball) and found that there was a marked increase in weight; he calculated that water was about 400 times as heavy, volume for volume, as air—that is, he put the density of water as 400 times that of air. We know that it depends on temperature also, but consider it about $\frac{1}{800}$th of the density of water.

One of Galileo's pupils was Torricelli (Evangelista Torricelli, 1608–1647); it is customary to refer to him as Galileo's pupil, but Torricelli only joined him a few months before Galileo's death, being then appointed as professor of mathematics at the academia at Florence to succeed Galileo.

The famous "Torricellian experiment" was performed in 1643 by Viviani, a one-time pupil of Galileo, but by now a student under Torricelli; Torricelli devised the experiment of filling a tube with mercury instead of water, and of seeing how high a column of mercury the air could support; Torricelli knew that mercury was about 14 times as dense as water, and so expected that it would be found impossible to have a vertical column of mercury "sucked up" a vertical tube for more than $\frac{1}{14}$th of the height found possible in the case of water—that is, $\frac{1}{14}$th of 30 feet, a little over 3 feet, that is some 70 centimetres. He considered that the air pressure could not balance a column of mercury of greater height than this; so that, consequently, if he merely pulled a piston up the tube, the lower end of which dipped below the level of mercury in an open dish, the liquid mercury would be pushed up by the pressure of the atmosphere on the exposed mercury surface, so that it *appeared* to be pulled or sucked up by the retreating piston, until it had reached a height of about 70 centimetres; and that if he continued to pull up the piston, the mercury would not follow, because it was not really being pulled up by the piston, but was being pushed by the external air ; and the limit of the pressure of the external air was just about equal to that due to his 70 centimetres of mercury. Moreover, as there would be nothing in the space between the top of the mercury column and the yet retreating air-tight piston, there must be a vacuum there, which Nature had forgotten to abhor.

His experiment was successful ; he did not publish his results, but described the experiment in a couple of letters, in 1644, to a friend of his, M. Ricci, of Rome ; we still have those letters, in one of which Torricelli said, nearly three hundred years ago, that his experiment was " not simply to produce a vacuum, but to make an instrument which shows the mutations of the air, now heavier and dense, and now lighter and thin ". In other words, Torricelli had invented a mercury barometer ; the external column of air supported the column of mercury, which is usually about 76 centimetres or 30 inches in height, above which existed that vacuum, relieved only by the presence of a little mercury vapour, which we now call a " *Torricellian vacuum* ". We have recorded an amusing result of students not seeing the written word, which occurred in an answer to a question in elementary science physics on the barometer. The candidate wrote thus : " At the top of the barometer tube is a torrential vacuum."

Torricelli having written to Ricci in Rome, Ricci was very excited, and wrote straight away to Père Mersenne, in Paris, who also was excited at the discovery of a vacuum and of a means of measuring atmospheric pressures after all these thousands of years. He appears to have told every other scientist in France about it ; they all, also, were excited, but none of them repeated Torricelli's experiment until the summer of 1646, because they had no suitable glass tubes, such as we have. In 1646 Pierre Petit, of Rouen, working with Pascal, repeated it. Pascal carried the matter much further, so you may as well have his full name—he was Blaise Pascal (1623–1662), and was an author, mathematician and physicist, born at Clermont, in the French Auvergnes. Pascal, thinking over Torricelli's experiment, said that if the mercury column were only pushed up by the pressure of the air, then the column should be shorter at higher altitudes. He tried it by taking a reading at the bottom and at the top of a church steeple at Paris, but his results were not sufficiently accurate to be conclusive, so he wrote to his brother-in-law back home in Auvergne and told him to try it on a high mountain there, the Puy de Dôme. They found a difference there at top and bottom of the mountain of three inches in the height of their barometer, which, as Pascal said, " ravished us with admiration and astonishment ". You, of course, are quite familiar with the idea that the barometric pressure drops about an inch for every 900 feet you rise vertically, and so probably refuse to be filled with admiration and astonishment.

All scientists now became quite interested in this work ; a lot of experiments were also carried out by the German, Otto von Guericke, who specialized, so far as this work is concerned, in the invention and production of air pumps. He was the first to weigh a sphere full of air, and then weigh it when the air had been removed by his " vacuum pump " and thus get the weight of the air removed, and its density. It was Otto von Guericke, also, who performed the famous experiment with what are known as the "Magdeburg hemispheres". He made two hollow hemispheres which fitted together smoothly as a hollow sphere $1\frac{1}{3}$ feet in diameter; when open to the atmosphere, the internal air pressure would be equal to the external air pressure, and the same would hold if the stop-cock at one end were then closed; but if all the air were pumped out from within the sphere, then there would be no internal pressure, and the two halves would be forced together by the outside air pressure; so that von Geuricke calculated that a force of 2,686 pounds weight would be needed to pull them apart. The test was made at Regensburg, before the German Reichstag and the Emperor Ferdinand III; instead of tying a rope to one hemisphere and fastening the other end of the rope to a tree and then harnessing horses to the other hemisphere to pull in the opposite direction, von Geuricke did what amounted to the same thing, but was more spectacular, since it required double the number of horses: he harnessed horses to *both* hemispheres to pull in opposite directions, and it was not until he had four pairs of heavy horses on each side, pulling against one another (that is, 16 horses altogether), that the hemispheres were pulled apart. Von Geuricke did lots of other experiments with his pumps which make very interesting reading; and he was apparently unaware of the earlier work of the Italians Torricelli and Viviani, or of the Frenchmen Pascal and Petit.

In England, Torricelli's work excited the interest of Robert Boyle. Boyle was really an Englishman, though born at Lismore Castle, in Ireland; he was the fourteenth child (though only the seventh son) of an English civil servant, Richard Boyle, who had the good fortune to be sent on an official mission to Ireland, where he married a very wealthy lady; later his great services to his country were recognized, and he was created Earl of Cork. The son, Robert, was fortunate in having plenty of money at his disposal to engage assistance and to buy material for his research work, but he was also a very brilliant scientist; so we owe much more to Robert Boyle than the law which some of you know: that the product of the pressure on a given mass of gas by its volume, is a constant, at unchanged temperature. That law Boyle found because he was annoyed by the silly criticisms of Franciscus Linus, Professor at Lüttich, in the Netherlands, whom I am sorry to immortalize by mentioning here; Linus claimed that the interpretation of Torricelli's experiment was all wrong, that the air was *not* elastic, and could *not* transmit pressures as Pascal said it did, but that the mercury in the barometer tube was hanging by invisible threads from the upper end of the tube, and that he had felt them when he closed the upper end of the tube with his finger. Boyle then carried out his famous experiments just to show that the air was elastic, or as he said, "the spring of the air is capable of doing far more than it is necessary for us to ascribe to it", to explain the phenomena of the Torricellian experiment. The experiment is described in text-books, and most of us today do it or have seen it done in our physics classes.

Boyle's work was repeated fourteen years after Boyle's published results were available by the Frenchman Mariotte, who was unaware that the experiment had already been performed; on the Continent, "Boyle's law" is unknown—it is referred to as "the law of Mariotte".

We see that in about five years from the first announcement of Torricelli's experiment, we had leapt from knowing nothing about the atmosphere and its pressure to the essentials of what you know today : that we live at the bottom of an ocean of air, exerting a pressure of about 15 pounds weight per square inch ; that the pressure drops as we rise, so that, whilst at sea-level the air pressure may be sufficient to balance a column of mercury 30 inches high, the mercury column would drop by an inch for every 900 feet we rose ; that the air is elastic, and that, taking a given mass of it, the volume of it is inversely proportional to the pressure to which it is exposed, temperature being unchanged ; that the space above the mercury in a barometer tube is a vacuum, except for the small mass of mercury vaporized there.

This article cannot concern itself with the chemistry of the atmosphere—that would demand yet more space—but it may interest you to know that the leaders into the examination of the chemical nature of the atmosphere, Priestley, Cavendish and Lavoisier, for example, carried on their work a hundred years later, in the period 1770 and onwards. One successful experiment on certain lines leads to a burst of others, followed frequently by a tranquil state ; thus we at the present moment are in a period of very active experiment, from which it will be difficult for future historians to pick the names of those associated with experiments of the greatest significance and stimulating value—not necessarily the most famous in their own time.