THE PIONEER IN THE HYGIENE OF VENTILATION.[1]

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I WISH to draw attention to the life and work of a great Englishman whose discoveries, although fully appreciated by those few persons who are versed in biological history, are not nearly so well known at the present day as they might be.

It has happened again and again in the history of discovery that some most important advances in a particular science have been made by persons not engaged in the professional pursuit of that subject. No doubt the formal recognition of public health as a science is of quite recent date, but there have always been those who have recognised the paramount claims of that branch of knowledge now embodied as hygiene or preventive medicine. Medical men, as might be expected, have in all ages been interested in measures which tended to the welfare of the community as distinguished from that of the individual only. But persons who were not medical men at all have, from time to time, either made suggestions of permanent value as touching the health of the people, or, going farther, have actually made contributions to the science of such a kind that without them progress in that science would have been greatly delayed. The truth of this is strikingly brought out in the life of one of the name of Stephen Hales, a clergyman of the Church of England, and a man who had neither studied medicine nor taken a medical degree, but who was nevertheless the first person in this country to make any serious attempt to provide for the systematic supply of fresh air to places where it could not enter by natural means.

The Reverend Stephen Hales, M A., D.D., F.R S., was *the* pioneer in the hygiene of ventilation. Mankind apparently did not arrive by "the light of nature" alone at a knowledge of the supreme importance of ventilation. Purely natural instincts *have* guided mankind to some results of great practical importance as regards health; he has long known that certain things are non-edible, certain waters non-potable, but as regards the quality of the air to be breathed and what constitutes impure air, the natural teachings are exceedingly ambiguous. The "natural man" is all right so long as he remains under the open heaven, but as soon as he surrounds himself with four walls he seems not to know he must constantly keep changing the invisible air around him. No doubt it is that because it is out of sight that air is also out of mind, but the fact is there are vast multitudes of people who never conceive of air as a real thing, as real as their meat and drink and just as necessary to be kept fresh. Doubtless the unpleasantness and even danger of moving air known as a draught is the reason why so many persons prefer not to attempt to have any fresh air at all. Even our most capable architects have by no means solved the problem of giving us plenty of fresh air without the concomitant of a draught. All living things vitiate air on breathing it even once, and all living things subsist by the absorption of oxygen. This oxygen being continually abstracted from the air breathed must be renewed from outside sources; thus air *must* be changed. Plants as well as animals need oxygen, and this was what Hales grasped, although he wrote and worked years before oxygen was discovered by Priestley and Lavoisier, and without knowing of Black's discovery of respiratory carbon dioxide. Hales in England and Leeuwenhoek in Holland, neither of them medical men, were about the beginning of the eighteenth century probably *the two* persons who saw more clearly than anyone else in Europe the prime necessity for ventilation—that is, the constant change of air in the neighbourhood of living beings. Hales did a very great deal else in science besides devising ventilators; he was a pioneer in the experimental method in both vegetable and animal physiology a hundred years before physiology as an experimental science existed in this country; as a benefactor to mankind it is not too much to say he is conspicuous in the first half of the eighteenth century. We know little indeed as to his capabilities as a pastor of men's souls, but it is certain he had great solicitude for their bodies; he introduced a water-supply into the village of Teddington; he actually contrived to ventilate the parish church, while his pamphlet against the abuse of alcohol is probably the first of its kind in England—"A Friendly Admonition to the Drinkers of Gin, &c.," published in 1734. This alone would enable him to rank as a pioneer in the advocacy of measures of practical hygiene.

Hales knew that air must be changed, whether air for plants or air for animals, air over grain in granaries, or over water stored for drinking purposes, or air enclosed in hot-houses, or air in mines or in holds of ships, or in prisons or around timber or gunpowder: air must be changed. He knew that fresh air was inimical to putrefaction, mouldiness, mustiness of every kind; he invented an apparatus for blowing air through drinking water stored in ships. Hales had the most definite conceptions as regards this necessity for oxygen without knowing what it was in the atmosphere that sustained life and without knowing in anything like its fulness the meaning and importance of Black's discovery that animals exhaled carbon dioxide from their lungs. For Black's discovery was published only some seven years before Hales died, and it is certain that Hales was not indebted to Black, but, on the contrary, Black was profoundly indebted to Hales. For he wrote: "I was partly led to these experiments by some observations by Dr. Hales in which he says that breathing through diaphragms of cloth dipped in alkaline solution made the air last longer for purposes of life."

In order to appreciate Hales's place in connexion with the discoveries in the chemistry of ventilation, allow me very briefly to recapitulate certain fundamental discoveries made both before and after his time. Carbon dioxide gas was discovered under the name of "*gas sylvestre*" by the Belgian chemist, van Helmont, about the year 1640 Van Helmont thought that when wood was burnt its "spirit," to which he gave the name of "gas," disappeared in a volatile form. The next contribution to the chemistry of ventilation was made by Thomas Willis (1621–75), who clearly laid it down that three things coöperated in the act of respiration—namely, a continual access of air, a constant supply of combustible material, and the continual removal of the products of combustion, for Willis clearly identified chemically the burning of a flame in air and tissue-respiration in a living animal. In 1660 the Hon. Robert Boyle performed the fundamental experiment as regards respiration and ventilation when he showed that long before a vacuum was perfect a sparrow and a mouse had both died and the flame of a candle had gone out. Boyle knew that something besides watery vapour rendered air unfit for further breathing. G. A. Borelli about 18 years later in Italy was the first to estimate what we now know as the "tidal air"—that is, the volume of air taken in and sent out at each breath, an important datum in connexion with ventilation problems. The Cornishman, Richard Lower, had before 1669 perceived that the expired air was noxious and must be removed; were there no need for this change, he writes, "we should breathe as well in the most filthy prisons as amongst the most delightful pastures." The next contribution was made by the Oxford man of science, John Mayow, who, working between 1668 and 1674, virtually discovered oxygen in a physiological sense. He named it "nitro-aerial particles," but he clearly understood that something which was absorbed by the air in breathing produced animal heat, and that that something was the same thing which was the cause of chemical combustion. Mayow died in 1679, and in England nothing was done as regards respiration or ventilation until Hales rediscovered a great deal that Lower and Mayow had known quite well. In some respects Hales was less of a chemist than Mayow, but he caused hygiene to advance to a vastly greater extent because he applied what little theoretical knowledge he had to the solving of problems of very definite practical utility. Less of a physiological chemist than Lower and Mayow, he was nevertheless the discoverer of a method of sustaining respiration in the absolutely irrespirable atmosphere of coal-mines and burning houses. He even suggested that his apparatus might be serviceable to divers; he was the father of all such as descend into "fire-damp" and "after-damp" and "choke-damp," &c., provided with an independent supply of air in an apparatus capable of absorbing one's carbon dioxide. He was the Jubal "of all

[1] The opening lecture in the class of Hygiene (Stage II.), delivered at the Midland Institute, Birmingham, on Sept. 15th, 1910, and fully illustrated by diagrams and portraits.

such as handle" the rescue-apparatus. But we must not imagine that although Hales devised such an apparatus he was acquainted with all the properties of carbon dioxide. For just as Van Helmont in the seventeenth century worked with the carbon dioxide of combustion without being acquainted with all its properties, so Hales in the eighteenth worked with the carbon dioxide of respiration without realising all that was involved in his researches on it. Respiratory carbon dioxide was discovered by Professor Joseph Black of the University of Glasgow in 1754. In point of time nitrogen was the next constituent of the atmosphere to be identified. This was also by a Scottish Professor, Daniel Rutherford, of the chair of Botany at Edinburgh; the year of this was 1772, the man a maternal uncle of Sir Walter Scott. Within two years more oxygen was separated by Joseph Priestley from mercuric oxide under the name of "dephlogisticated air." By 1775 Priestley had found that this gas supported both combustion and respiration, but he did not fully understand all that was involved in his discovery; as we are all aware, it was Lavoisier who knew what he was working with when he had, by the end of 1774, isolated oxygen gas and given it the name which has ever since clung to it. The details of the life of Stephen Hales are neither numerous nor romantic. The son of Thomas, eldest son of Sir Robert Hales of Beckesbourne, Stephen was born in 1677 near the pleasant village of Beckesbourne in Kent, not far from Canterbury. His mother was Mary, daughter and heiress of Richard Wood of Abbots Langley. At the age of 19 he went to Corpus Christi College, Cambridge, where he graduated M.A. and took his B.D. degree in 1711. His early scientific leanings may be inferred from his having studied anatomy, chemistry, and botany as a recreation. As a student he managed to make a cast in lead of the lungs of a dog, and he constructed a "planetarium in brass" or orrery as it was called on Newtonian principles.

Having taken Holy Orders, Hales was presented in 1710 to the perpetual curacy of Teddington in Middlesex; it was here that he carried out by far the greater number of his experiments. In 1718 he was elected a Fellow of the Royal Society, and 22 years later he was awarded the Copley medal, the highest honour in the gift of that learned body. In 1732 Hales was appointed one of the trustees in the newly founded colony of Georgia. In 1735 he was elected one of the eight foreign members of the French Academy in room of the late Sir Hans Sloane at the time of his death President of the Royal Society. The date of Hales's marriage is uncertain; it is thought to have been about 1719; his wife died childless in 1721; he did not marry again. Until within a year or two of his death Hales communicated the results of his manifold researches in the form of papers to the Royal Society. He published independent treatises as well; his classical "Vegetable Statics" saw the light in 1726, and the equally famous "Hæmostatics" or Vol. II. in 1733. Both were dedicated to George II.

Although, then, Hales made researches in, and wrote extensively on, vegetable and animal physiology, on chemistry, medicine, and surgery, it is as a pioneer of sanitation that he must ever live in our grateful remembrance. He did not approach problems in ventilation from the purely theoretical side, but he designed workable apparatus on the principle of the bellows for drawing the air from places particularly badly situated as regards air-supply. The earlier and smaller forms were worked by hand, the latter and larger were driven by a windmill, but the construction of them all was essentially the same as that of bellows for church organs. Hales gives the velocity of the air outflow from these bellows as 6¼ miles per hour.

Hales's first paper on the importance of ventilators in mines, hospitals, prisons, and ships was read to the Royal Society in 1741. In this paper he speaks of "the rancid vapours from human bodies" which inclines us to think that even at this early date there were glimmerings of a distinction between respiratory carbon dioxide and noxious vapours exhaled from the skin and lungs. Certainly it is very interesting to be told that the latest opinion is that the headache and distress of ill-ventilated places are due not so much to carbon dioxide *per se* as to the moisture, the heat, and the volatile organic effluvia. But Hales had grasped the important fact that breathed air must be got rid of and sent outside into the ocean of the atmosphere. At the date of which we are speaking, to be sent to prison was practically to be condemned to die from gaol fever; prisons did not seem to have been ventilated in any way whatever. When a Lord Mayor of London, two judges, and an alderman had all died from gaol fever caught at the Old Bailey sessions, a committee of the Royal Society was appointed to report upon the state of ventilation in the gaols. Hales was one of this committee; it reported that Hales's ventilators should be installed, and by 1749 they were in working order at the Savoy Prison. Between the years 1749 and 1752 four prisoners died there from gaol fever, compared with 50 to 100 per annum previously. In 1752 the ventilators actuated by a windmill were introduced into Newgate Prison; from each apparatus ducts led to 24 cells or wards. The mortality in subsequent years was very markedly decreased.

In 1753 Hales wrote an article in the *Gentleman's Magazine* on the applicability of his ventilators to army hospitals and private houses. Nowhere was his invention appreciated more than on board ship. Ships were at this time floating strongholds of death; what between scurvy and ship fever due to poisoning by bad air, only the most robust men survived for any length of time. By 1755 Hales was able to report improvement to the Royal Society in a most interesting paper with the following title, "An Account of the Great Benefits of Ventilators in many instances in Preserving the Health and Lives of People in Slave and other Transport Ships." Hales received most gratifying reports from ship captains as to the enormous change for the better which had been introduced into the conditions of life in the Mercantile Marine. Thus a Captain Thomson under date, London, Sept. 25th, 1749, writes: "All agreed the ventilators were of great service. The men did not need to be urged to work them. 200 men aboard for a year, pressed men from gaols with distemper, all landed well in Georgia. This is what I believe few transport or any other ships can brag of, nor did I ever meet the like good luck before which ..... I impute to the benefit received by the ventilators." Similar reports came from a Captain Ellis, who made a number of voyages in slave transport ships; he had at one time under his care as many as 312 negro slaves who were all landed alive and well at Bristol. Equally encouraging reports came from the transport ships to Nova Scotia.

Through the instrumentality of the French man of science Du Hammel, Hales contrived to have his ventilators installed in certain prisons in France where English prisoners were confined. The reverend sanitarian closes his paper of 1755 with these words: "..... they little consider that it is a high degree of putrefaction (that most subtle dissolvent in nature) which a foul air acquires in long stagnating which gives that pestilential quality which is called the gaol-distemper, and a very small quantity or even vapour of this highly attenuated venom, like the infection or inoculation for small-pox, soon spreads its deadly infection." Hales is, of course, writing of typhus fever; the pathologists are still uncertain as to the etiology of this fever, but practical sanitarians have all but banished it from Great Britain. We ought not to forget that the initial intelligent stages of the war against typhus fever were undertaken by Stephen Hales; he saw perfectly well that the question of its abolition was bound up with the problems of ventilation generally.

[A drawing of the first artificial breathing apparatus which was capable of absorbing the exhaled carbon dioxide was here thrown upon the screen. Dr. Harris proceeded:]

You will note that it is nothing more than a bladder divided into compartments by four partitions of flannel or linen soaked in a solution of potash. To use the particular form which I show you, the nostrils had to be closed, as they have to be in all mouth-breathing forms of similar apparatus. This particular form held only between 4 or 5 quarts of air, but Hales thought that one containing a gallon of air could support respiration for at least five minutes. Now, it seems to me particularly interesting, in view of the prominence which life-saving apparatus has obtained at the present day, in view of the fact that the Government has already legislated in regard to their use, and is about to legislate on a still larger scale, to know that before 1726 a practical attempt had been made to construct an artificial respiration apparatus. This simple invention is the humble parent of all the various ingenious forms of life-saving apparatus at the present day—the Fleuss, the Draeger, the W.E.G., the "Meco," and others—which enable men to remain for upwards of two hours in atmospheres not merely poisonous but actually deadly. As I have told you,

it was this invention of Hales that inspired Black to discover respiratory carbon dioxide. This is not the place to refer even in the most general way to the enormous amount of work which Hales did in founding the science of experimental botanical physiology, but at least you ought to know that it is to him we owe the mercury manometer. Every junior medical student knows that it was Hales who first experimentally demonstrated the magnitude of the arterial pressure of the blood in the living animal (mare), but he made experiments over the whole field of animal physiology, and was well acquainted with previous work both in England and on the continent. He might have been a practising surgeon, so interested was he in the subject of stone in the bladder. In physical science he wrote on earthquakes and invented an instrument for determining the depth of the ocean. He also invented a method for dredging harbours.

In private life Hales was very modest, approachable, genial, and full of pastoral charity. The poet Pope, his neighbour at Twickenham, to whose will he was a witness, had the highest opinion of him personally. Sir J. E. Smith, his contemporary, said of him: "His philosophy was full of piety"; and from all we can gather, although his sermons were very dull, he was by no means lax in the performance of his duties as the pastor of his flock.

In closing this very imperfect account of Hales I cannot do better than quote what is carved below the marble monument to his memory in Westminster Abbey which was erected by the Princess Dowager of Wales, mother of George III.; it will at least let you know what contemporary opinion of him was: "..... above the dead prophet divine Wisdom proclaims—'he was skilled in helping men's troubles, he too in tracing God's works; no lapse of time will weaken your praise, great Hales! or your titles, England is proud to enroll you amongst her noblest sons, England who can boast a Newton.'"

While we congratulate ourselves on having attained to an understanding of the principles of ventilation; on having abolished typhus fever from our hospitals, prisons, and ships; on having devised apparatus for sustaining life in irrespirable and deadly atmospheres, let us not forget that the initial stages in the comprehension of these things were worked out, not by any high placed, well-paid, public official, but by a modest amateur, the scientifically-minded country clergyman, Stephen Hales.

THE BENENDEN SANATORIUM AND INDUSTRIAL INSURANCE FOR THE TREATMENT OF PHTHISIS.

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THE first sanatorium of the National Association for the Establishment and Maintenance of Sanatoria for Workers suffering from Tuberculosis was opened at Benenden in March, 1907. It now contains 68 beds in the main building attached to the administration block, 20 beds in a cubicle pavilion, 11 beds in a second pavilion, and 2 beds in a chalet. The first of these separate buildings (for 20 beds, built and furnished for £900 on Mr. West's designs) was erected by subscription among Post Office servants and was handed over to the association by Mr. Herbert Samuel on Sept. 12th. The second was built by friends of the late Countess Cadogan and is to be handed over shortly. The chalet was given by Dr. Foster Owen and is the one exhibited by him at the Whitechapel Exhibition of the National Association for the Prevention of Consumption. The beds are self-maintained, almost entirely by workers' organisations, the largest and most successful of these being the Post Office Sanatorium Society, organised by Mr. C. H. Garland, its secretary, who is also chairman of the association. This society maintains 35 beds, the cost of insurance being under ½*d.* per week per member (2*s.* per year), the society being a voluntary organisation of postal servants and the subscriptions being deducted by arrangement with the Postmaster-General at the rate of 1*s.* per member half-yearly. The figures of this society prove that 2000 men subscribing ½*d.* per week can easily maintain one bed, admitting an average of three patients a year, and pay all office expenses and the cost of travelling from any part of the kingdom. The London Hospital Saturday Fund retains 15 beds, the Hearts of Oak Benefit Society five beds, the Club and Institute Union two beds, the Manchester Unity Order of Oddfellows five beds, the South London District of Foresters (by a voluntary association), the Royal Oak Benefit Society, the Typographical Association, the Amalgamated Society of Railway Servants, and the Railwaymen's Convalescent Homes one bed each, and the Southwark borough council (under special rules defining the class of patients) five beds.

The friendly societies are unable, under their Acts of Parliament, to erect buildings for such purposes, and, in the present financial position of these societies, the funds available for maintaining beds are limited and have to be most carefully considered. All acquainted with friendly societies' work know that a great number of voluntary levies are continually being made, and it is a question still, after seven years' strenuous education of the members and executives of these societies, how far it is possible for large voluntary associations to be formed inside them for the insurance of phthisis treatment. The only one existing is that in the South London District of Foresters, organised by Mr. Chapman, and it is believed that the educational effect of this insurance in this district has already considerably reduced the annual cost of consumption to the ancient Order.

As advisory physician to the council and as medical superintendent of the institution we always insist upon the educational aspect of the sanatorium, following Dr. Newsholme. This institution in relation to the industrial classes is best defined by the title of a paper contributed to THE LANCET some years ago by Mr. Garland and Dr. Lister—"A National School for Consumptives." This phrase, for which Dr. Lister was responsible, expresses, we venture to think, the point of view that should be adopted in the proposed provision of State-supported sanatoriums. The results so far show that over 80 per cent. of the patients discharged from Benenden in an "arrested" state of their disease are in full work (after six months to two years). Some of those not doing any work are in good health, but out of employment for other reasons.

There is no doubt that the danger of not being employed on discharge causes a certain amount of late application, patients waiting until the disease is comparatively advanced, among the members of all the affiliated societies except that of the Postal Society, whose cases apply earlier, and who can obtain up to six months' leave for treatment with the approval of Mr. A. H. Wilson, the chief medical officer of the Post Office. The postal workers are also selected "lives," and hence, perhaps, more resistant. In addition, the Postal Society has caused a definition of the disease, drafted by Dr. Lister, to be hung in every post-office of the kingdom, with the approval of the present Postmaster-General, Mr. Herbert Samuel, and his predecessors, the present Lord Derby and Mr. Sidney Buxton. The association and the Postal Society are largely indebted to these gentlemen. Fear of the loss of employment on entering a sanatorium is also a factor in producing advanced cases which have to be rejected, the evil day being postponed and money wasted on quack medicines until too late. Postal servants enjoy the advantage of long sick leave, reinstatement if they respond well to treatment, and special allowances by the State in case they are unfit for further service. Few workmen can get such terms from their employers, and the fear of their position on discharge from the sanatorium is also a cause of late application for treatment.

Intelligent understanding by general employers of the enormous educative value to early cases of residence in a sanatorium and its effect on the health, not only of the individual but on his fellow workers (as shown by Mr. Chapman in the Foresters), should be one of the objects in the campaign against industrial tuberculosis. The danger of extra claims (for "aggravation of existing disease") under the Employers' Liability Act and Workmen's Compensation Act which may be feared by some employers does not seem to have arisen in the Postal Service, and is not a