From *Tractatus Quinque*
(Oxonii, e Theatro Sheldoniano. 1674)

Two Oxford Physiologists

Richard Lower 1631 *to* 1691
John Mayow 1643 *to* 1679

BY

FRANCIS GOTCH, M.A., D.Sc., F.R.S.

WAYNFLETE PROFESSOR OF PHYSIOLOGY, UNIVERSITY OF OXFORD

(OXFORD UNIVERSITY EXTENSION SUMMER MEETING, 1907)

OXFORD
AT THE CLARENDON PRESS
MCMVIII

HENRY FROWDE, M.A.
PUBLISHER TO THE UNIVERSITY OF OXFORD
LONDON, EDINBURGH
NEW YORK AND TORONTO

TWO OXFORD PHYSIOLOGISTS

RICHARD LOWER (1631–1691)

JOHN MAYOW (1643–1679)

THE seventeenth century was an epoch in the history of Natural Knowledge, and the University of Oxford was directly concerned in its production through a series of scientific discoveries made between 1650 and 1680.

The remote source of the remarkable activity of this period was the Renaissance, that extraordinary quickening of the human intellect which, commencing in Italy during the fifteenth century, spread from thence to other countries until it finally reached England.

The revival of learning did not necessarily involve a corresponding development of natural science, for the growth of natural knowledge is related, not so much to a desire to revive the past, as to a feeling that it is necessary to investigate the present; it is indeed possible that the temper of the Renaissance, by exaggerating the importance and value of the classical writings, may have tended to hinder that freedom of speculative inquiry which is so potent for science. But, as always happens in periods of intellectual activity, sooner or later attention and speculation were directed to natural phenomena free from the bias of authority; and it is now generally accepted that the two founders of modern science were sixteenth-century Italians, Vesalius on the biological and Galileo on the physical side.

Vesalius, Professor of Anatomy in the University of Padua, died in 1564; his great published work (*De* *corporis humani fabrica*) dealt with the structure of the human frame and was published in 1543. In this he set forth the facts which he had discovered by actual dissection, and thus laid the foundation of Modern Anatomy. His reward was characteristic of the age in which he lived, for he was condemned by the Roman Church to make a long pilgrimage, in order, if possible, to expiate the crime of dissecting the dead human body and the sin of stating facts in contradiction to those which the Church had accepted once for all on the authority of the ancients. The pilgrimage involved visiting the most notable shrines of Europe; it was begun but never carried out, for Vesalius died in the endeavour to fulfil the sentence of the Church.

In spite of ecclesiastical opposition, the truths discovered by Vesalius prevailed, and his successors in Padua, Columbus, Fallopius and Fabricius, all unflinchingly pursued the path which their great predecessor had trod. To the last of these, Fabricius, there came in 1598 a young English student, one William Harvey, to whom Fabricius showed his curious discovery of the valves which lined the body veins. Thus the new development of biological science was transplanted from Italy and took root in the soil of England, where Harvey, by his demonstration of the circulation of the blood in 1615 and his treatise upon the heart in 1628, did for Physiology — that is, the body functions — what Vesalius had done for Anatomy, the body structure.

It must be remembered that all men are hampered by the current beliefs of their age. Throughout the sixteenth century these were so saturated with mysticism that the Renaissance period, in spite of its quickening influence on thought, showed, as regards the intelligent appreciation of scientific conceptions, great intellectual limitations. In a recent book by Miss Sichel upon Catherine de Medici this is happily expressed by the remark that, in regard to this period, both 'its powers of production and its absence of discrimination are alike surprising; eternal mysteries were clearly proved by logic while plain scientific facts were wrapped in a dense obscurity'. In confirmation of this we have only to remember that astrology and alchemy took the place of astronomy and chemistry.

Not until the lapse of a century did the heirs of the Renaissance begin to discriminate the scientific truths which the mystic verbiage of the time enshrouded, and it is the great glory of Harvey that he was one of the first to make this nice distinction and was thus enabled to disclose the cardinal fact of human physiology. He was succeeded in England from 1650 to 1700 by a galaxy of talent devoted to the study of natural philosophy by means of observation and experiment. In this galaxy Oxford names are conspicuous. Some of these names are familiar; Robert Boyle, Christopher Wren, and Thomas Willis, but I doubt if the two men who form the subject of my lecture to-day are known by name to many of my audience; and yet one of these, Richard Lower, possessed remarkable gifts which he utilized in a notable way for the advancement of natural knowledge, whilst the other, John Mayow, was one of the greatest scientific men of the seventeenth, or indeed of any century.

Little apology is therefore required for restricting this lecture to an account of the lives and labours of these two natural philosophers. Such account should possess more than an antiquarian interest, for, if properly set forth and duly appreciated, it ought to exercise a wholesome influence upon our thought. We may learn from it what are the peculiar difficulties which beset all scientific investigation, whether in the seventeenth or in the twentieth century; difficulties arising from the paralysing influence of authority or false tradition, and from the misleading effect of inaccurate observation or erroneous interpretation; we may see how the advance of science is at one time accelerated, at another time retarded through the unequal flights of the scientific imagination leaping beyond the obvious fact, now on to the firm foothold of fruitful hypothesis and now on to the shifting quicksands of sterile fancy; whilst through it all we should be able to discern the mark of the true scientific spirit which labours without prospect of pecuniary reward, sustained by the belief that an achieved result, however small, must enlarge the realm of natural knowledge.

Richard Lower and John Mayow were both Cornishmen; Lower, twelve years older than Mayow, was born in 1631 near Bodmin; his father, removing to London during the troubled times which preceded the Civil War, sent the lad to Westminster School, where he seems to have profited sufficiently to obtain, in 1649, a studentship at Christ Church, Oxford; four years later he took the B.A. degree. He then devoted himself to the study of Medicine, and helped in the anatomical work of the celebrated Dr. Willis, at that time Professor of Natural Philosophy; he also studied such aspects of Chemistry as were now slowly emerging from the romantic mysteries of Alchemy, as set forth by one Peter Sthael, a foreigner introduced to Oxford by Robert Boyle.[1] In 1665, after carrying out several important researches, he took the Doctorate of Medicine. He became noted for his anatomical skill and for his

[1] See Note A.

investigations upon the heart and blood, and he acquired great celebrity when, in 1665, he demonstrated at Oxford the possibility of transfusing the blood from one animal into another. This, and the circumstance that Willis had now gone to London, induced Lower to go to London himself in 1666, where he became a Fellow of the Royal Society and one of the prominent physicians of the day. When Willis, who was court physician, died in 1675, Lower succeeded him, and thus commenced a short period of worldly prosperity, for Wood states that he was now 'esteemed the most noted physician in Westminster and London, and no man's name was more cried up at court than his'.[1] Lower did not, like many men in this troublous time, sacrifice his principles in order to retain his professional position, but remained a pronounced Whig in politics, and as such began to decline in favour, during the last years of Charles the Second's reign. On the accession of James the Second he was deprived of his court appointment, fell into disrepute, and shortly after seems to have retired to his native county, Cornwall, where he died in 1691, being then in the 60th year of his age, and was buried in the Church of St. Tudy, near Bodmin. He must have been in fairly prosperous circumstances, since he left by his will £1,000 to St. Bartholomew's Hospital. All the excitement created by his early experimental work now failed to save his name from being treated with contemptuous indifference. It is difficult to acquit John Evelyn of political rancour when it is realized that although, as a prominent Fellow of the Royal Society, Evelyn makes frequent reference in his Diary to the observations brought forward at the meetings of that Society, yet the only mention he makes of Lower is the following:—

[1] See Note B.

'Had much discourse' with Lord Normanby 'concerning Charles the Second being poisoned. Also concerning the Quinquina, which the physicians would not give the King at the time when, in a dangerous ague, it was the only thing that could cure him (out of envy because it had been brought into vogue by Mr. Tudor, an apothecary). . . . Being asked why they would not prescribe it Dr. Lower said it would spoil their practice or some such expression.'

This contemptuous reference to Lower was made by Evelyn in 1695, four years after Lower's death.

John Mayow was descended from a genteel family of this name residing at Bree in Cornwall; his parents, however, were living in London when he was born, in May 1643, in the parish of St. Dunstan-in-the-West. He showed early signs of his extraordinary talents, for at the age of fifteen he was entered as a commoner in Wadham College, and the next year, 1659, was admitted as a Scholar, whilst in his second year at Oxford, when seventeen years of age, he was elected to a Fellowship at All Souls College. Here he studied law and incidentally medicine; he took the B.C.L. Degree in 1665 and the D.C.L. in 1670, he also obtained the privilege of practising physic although he had not the medical degree of the University.[1]

Various expressions in his writings indicate that he was attracted by Lower's ability and used to avail himself, through Lower's position as Willis's chief assistant, of the opportunities thus afforded for becoming acquainted with the chief facts of anatomy and with the scanty chemistry which was then in vogue; Willis himself must have soon realized the brilliance and extraordinary gifts of this young Oxford Fellow. The remarkable character of his scientific conceptions will be set forth in detail later, but a general idea may be

[1] See Note C.

derived from the circumstance that in 1668, in the twenty-fifth year of his age, he published his first work, the *Tractatus de Respiratione,* in which he showed that there was a special vapour or gas in the air necessary for both combustion and life; thus, more than a hundred years before Priestley and Lavoisier, he had discovered Oxygen. In 1674 a second larger work was published, the celebrated *Tractatus Quinque,* which dealt with the nature of combustion along almost modern lines, and, what is still more remarkable, with the source of the body heat, which he showed to be situated in the muscles, a physiological conception which was not really taken seriously until Helmholtz substantiated it two hundred years later.

These treatises were printed by the University Press, then located in the cellars of the newly erected Sheldonian Theatre; and the second one contains an exquisite portrait of the author.[1] This portrait shows, in its delicate moulding of Mayow's features, the intellectual character of his expressive face, with its luminous eyes and sensitive mouth, the whole presenting a personality possessed of singular charm: it gives the impression of one of those gifted beings who, blossoming early, too often fade away before other men have reached their full maturity. In 1675 he left Oxford and went to Bath, where he set up as a practising physician; here he made a scientific investigation of the salts contained in the well-known Bath waters. For this comparatively trivial work he was elected a Fellow of the Royal Society on November 30, 1678; and in the next year, 1679, when in the thirty-sixth year of his age, he died 'in an apothecaries house bearing the sign of the Anker in York Street, Covent Garden, London, having a little before been married not altogether to his content'. He was buried

[1] See Note D.

in St. Paul's, Covent Garden.[1] His early death was a lamentable blow to science, for no one, except perhaps Lower, recognized the true significance of his discoveries, whilst his scientific conceptions were so misunderstood that they exercised no influence upon either his contemporaries or his successors. The true principles of chemical combustion and the application of chemical conceptions to physiology thus remained unappreciated for more than a century.

Before describing the discoveries and scientific conceptions set forth by Lower and Mayow, it is desirable to briefly consider the state of scientific knowledge in 1650, at least as regards Anatomy, Chemistry, and Physiology.

Anatomy, that is the general structure of the body framework, was the most advanced of these three subjects, for ever since the time of Vesalius it had been studied by the sound method of dissection; there were, however, obvious imperfections, mainly due to the circumstance that suitable means of aiding the eye by means of microscopic lenses were not then available. The finer parts of the animal framework remained, therefore, in complete obscurity, and Harvey himself, although he demonstrated that the blood must travel along the arteries and go from there to the veins, could not form any idea as to how it crossed from the fine endings of the one set into those of the other. The anatomy of the nervous system was in a particularly backward condition, the appropriate display of the cerebral structure even by means of dissection being regarded as a work of almost superhuman difficulty.

The same ignorance existed in regard to the sense organs, so that even the leading oculists were ignorant of the structure of the eye. Thus Pepys says: With

[1] See Note E.

'Turberville, my physician for the eyes, and Lowre, to dissect several eyes of sheep and oxen with great pleasure and to my great information. But strange that this Turberville should be so great a man and yet to this day have seen no eyes dissected or but once, but desired this Dr. Lowre to give him the opportunity to see him dissect some.' Yet according to Pepys, when he consulted Turberville about his eyes, the latter did him good, although he only discoursed learnedly about them.[1]

Chemistry was in a still more rudimentary state; it inherited from its parent, alchemy, the suspicion of being akin to necromancy and witchcraft, and its study was, for some time, regarded as a degrading occupation.

In the complete edition of the Philosophical Works of the Honourable Robert Boyle, the editor, Dr. Shaw, introduces a vindication into the preface of the particular treatise entitled 'The Sceptical Chymist'. This states that 'Mr. Boyle hath been censured by some learned men for cultivating an art (chemistry) which they apprehended to be unworthy of him,' but (says the editor) chemistry 'is so far from being an employment unworthy of a gentleman and philosopher, that it is one of the principal whereto he ought to addict himself who would improve either philosophy or physic'.

Now Chemistry is essentially the science of matter; it deals with the properties of the elementary substances which are revealed in the various kinds of matter, with their modes of combination and dissociation, and with the forces which are either locked up or released through these processes. But in mediaeval thought the elementary substances were limited to four; fire, air, earth, and water. Valentine, a Benedictine monk who lived at Erfurt towards the end of the sixteenth century, had extended this crude conception, and the various

[1] See Note F.

forms of the earth element were regarded by the most notable of his successors, such as Paracelsus, as being for the most part compounds to which three elementary substances contributed, salt, sulphur and mercury. All the common substances which could be burnt were supposed to be salino-sulphureous combinations of different types. Combustion was regarded as the peculiar property of sulphur; this held in its pores a subtle spirit which was thrust out when the substance was heated and then became visible as flame. The theory as to the action of the heat upon substances was that it set the sulphureous particles into a violent turmoil technically called an 'effervescence', and that in consequence of the bubbling and consequent friction of these particles an 'incension' occurred, releasing the spirit of fire; thus every substance lost something when it was burnt.

Even the acute intellect of Boyle could find no more appropriate language in which to describe flame than that 'its particles were either of a saline or a piercing terrestrial nature'.

With these crude notions of chemistry, it will be clear that, in spite of the light shed by Harvey's great demonstrations upon physiology, such physiological conceptions as are based upon the chemistry of the matter contained in living things must at this date have been very primitive. Physiology, the science of the body functions, was mainly, if not entirely, human. The body was believed to be pervaded by certain humours arising from the liver, the spleen, and other organs, whilst the various body activities were carried out through the capricious flow of vital spirits whose action could be greatly modified by the presence of these humours. Three phenomena were, however, so obvious that every natural philosopher felt bound to admit their importance in connexion with life, and accepted with little demur the teaching of the ancients as a sufficient explanation.

The first of these was the imperative necessity for food and drink: in regard to drink, it was clear that the water washed out the bad humours, but food was believed to form the essential humours by means of its salino-sulphureous compounds; hence the nature of the diet determined whether your humours were beneficial or malevolent; and appropriate variations in diet by altering your humours could transform your whole temperament and character.

The second was the obvious fact that the living body was warm whereas the dead body was cold; but, since the cessation of the motions of the heart was rightly regarded as the immediate cause of death, it was generally believed that the heart produced the body heat. This it did because it was the seat of an 'effervescence' in the salino-sulphureous particles of its contained blood, and thus an 'incension' occurred within the left ventricular cavity where there emerged continuously the vital flame which warmed the whole body. The heart-beat and the effervescence were believed to be two aspects of the same thing, so that the one could not occur in the absence of the other; hence the cessation of the heart-beat was contemporaneous with a similar cessation of the effervescence, and death occurred because the vital flame was quenched when the heart stopped its pulsations.

The third phenomenon was the inexplicable mystery of respiration. Although respiration was recognized by Hippocrates as necessary for life, it remained for centuries the sport of contending fanciful explanations. Boyle, writing at the same time as Lower and Mayow, gives an instructive account of the prevalent confusion of thought on this subject, and says: 'As to why the inspiration and the expiration of air are so very necessary to life both naturalists and physicists differ so widely that it will be difficult either to reconcile their opinions or determine their controversies'. It would seem that, among these irreconcilable views, the following were those most generally held. Many supposed the chief use of respiration to be to cool and temper the heat evolved in the heart by the effervescence of the blood within it, which would otherwise become insupportable; to this view was appended the supposition that the coldness of the air entering the chest condensed the blood, which, as Harvey had shown, must flow through the lungs from the right to the left side of the heart; hence this blood condensed in the lungs gained such a consistence as was requisite to make it fit fuel for the production of the vital flame in the left ventricle of the heart. Another view was so opposed to Harvey's discovery of the circulation as to be only held by those who declined to credit his demonstration; this assumed that the movement of respiration was the mechanism which served to pump the blood to and fro in the body, and that the entry and exit of air was a mere incident of no physiological importance. The most thoughtful philosophers, however, supposed that the air in some unknown way actually reached the left ventricle of the heart through the blood, and not only tempered the heat evolved there, but provided material for the generation of mystic vital spirits; they also supposed that the effervescence of the blood in the heart caused the production of peculiar vapours or 'steams' which had to be removed from the body by the lungs in the steaming breath, and that a principal object of respiration was to disburthen the blood of 'its excrementitious steams'.

Boyle rejected the last of these suppositions because he found that animals rapidly died if they were placed in the receiver of his air-pump and the receiver then exhausted of its air, and he pertinently remarks that since the ambient space is left much more free to receive any 'excrementitious steams', the cause of death could not be the choking up of these in the body. He concluded that 'a certain consistence of air' is requisite for respiration and for life, and said that 'there must be some use of the air which we do not thoroughly understand that makes it so necessary for the life of animals'.

He notes further that 'the lungs sometimes oddly convey things to distant parts of the body', but he contented himself with the mechanics of the filling of the lungs, and declined to grapple with difficult problems as to the functions of respiration. Thus in his physico-mechanical experiments he says: 'It may here be expected that I should attempt to clear the nature of Respiration, but I pretend to go no further in it than our engine' (the air-pump) 'leads us'.

It is indeed remarkable that a man of Boyle's intellectual power, who made numbers of experiments upon animals with the newly invented air-pump, should have been unable to suspect the presence in air of a special ingredient essential for both combustion and life. But he seems to have been one of those men who, while possessing acute powers of observation and remarkable ingenuity, lacked that boldness in the scientific use of the imagination which alone can reach beyond the obvious fact and reveal the unknown. In this respect he was much inferior to both Lower and Mayow. Thus, after observing that both birds and mice died in a receiver which had been exhausted of its air, Boyle writes in a way which shows both his merit and his weakness. 'Though,' says he, 'there appeared not much cause to doubt but that death proceeded rather from the want of air than that the air (space) was overclogged by the steams of their bodies exquisitely pent up in a glass, yet I *that love not to build anything upon conjectures*, thought it the safest way to obviate objections and remove scruples by shutting up another mouse as close as I could in the receiver.' I fear that Boyle was but a timid philosopher when faced with a problem which demanded not only experimental skill but boldness of conjecture to probe its mystery.

As regards such other physiological facts as muscular motion, the function of nerves, the brain, the senses, and so forth, there was in the early part of the seventeenth century little knowledge or even speculation worth recording, for muscles, nerves, brain, and sense organs were considered to be the playground of vital spirits, *ex hypothesi* unknowable, and with activities depending upon their caprice, their likes and dislikes; in short, upon their affections.

To such a world of crude scientific notions were Lower and Mayow introduced on their coming to Oxford, and here they both studied Anatomy, the most reliable science of that day, and the Chemistry of the salino-sulphureous compounds; as regards this chemistry it is worth remembering that the first Chemical Laboratory in any University was that erected about 1660 by the Curators of the University of Leyden in order to enable Sylvius, then Professor of Medicine, to carry on investigations upon saline substances and particularly upon sal-ammoniac, the *sal mirabile*, discovered by his predecessor, Glauber. It is therefore clear that the chemistry studied by Lower and Boyle at Oxford would have but little in common with what now forms the subject-matter of this extensive science.

Under such limitations these two men men evolved the modern scientific conceptions which I will now endeavour to put before you, commencing with the work of the senior of the two, that is Lower. Lower seems to have specially impressed his contemporaries by his remarkable anatomical skill, and he is always alluded to as 'that expert anatomist'. His skill attracted the attention of Dr. Willis, who was then engaged in the task of endeavouring to work out the structure of the brain. In his celebrated book *Cerebri Anatome*, published in 1664, Willis refers in his preface to the help given him by Lower, whom he styles 'a physician whose knowledge of the brain and skill in Anatomy are of the highest order'. He goes on to say that 'with Lower's co-operation and assistance hardly a day passed without some anatomical experiment', and that particularly in the difficult task of the dissection of the pairs of the cranial nerves 'my friend's wonderful skill shone forth as well as his unwearied labour and an industry that no obstacle could impede'. Lower was not only a skilful anatomist but an excellent draughtsman, and Willis expresses his thanks for admirable plates delineated by Lower's own hand. Foster regards the scientific renown of Willis as almost entirely due to the work of Lower, and in his History of Physiology refers to Lower as a 'singularly able man, the henchman of the fashionable Willis whose false fame in large measure rested on Lower's careful unacknowledged work'.[1]

As a matter of fact, however, Willis acknowledges handsomely enough that without Lower's help he could not have succeeded in unravelling the anatomy of the brain and cranial nerves, whilst Lower's first publication in 1664 shows that he felt in no sense slighted by his senior colleague, for the publication is entitled

[1] See Note G.

A Vindication of Dr. Willis's diatribe upon Fevers.' The Vindication forms only a portion of the book, which contains many bold speculations. It commences with an inquiry as to how far a fever consists of an 'effervescence' of the blood, and what is the nature of such effervescence, but it goes on to such physiological inquiries as the following. Whether there be both nervous and nutritious juices. How nutrition is performed. What is the nature of blood? What difference there is between the Venal and the Arterial blood, and for what uses both the one and the other are particularly designed. What the uses of the lungs are in hot animals? What life is? Whence the soul of Brutes? The publication attracted the attention of the newly-formed Royal Society, and an abstract of it was printed in the first volume of the Society's tracts, which, after quoting the above points, concludes by stating that 'many other such material disquisitions are to be found in this small but very ingenious and learned treatise'.

Towards the end of February 1665, Lower performed an experiment in connexion with work on some of the above-named topics which made him for a short time a celebrated man. This experiment was the transfusion of the blood from one animal into another. The suggestion which led to this experiment seems to have been thrown out by Christopher Wren. It was performed at Oxford in the presence of Doctors J. Wallis, Millington, and several other doctors of medicine and scientific men. The transfusion experiment was repeated by Lower before the Royal Society in London, and at once gave rise to the most exaggerated expectations, for Lower said he 'intended the experiment to be prosecuted to the utmost variety the subject will beare; as by exchanging the blood of Old and Young, Sick and Healthy, Hot and Cold, Fierce and Fearful, Tame and Wild, animals'. Lower himself affirmed that this exchange of blood 'doth not alter the nature or disposition of an animal', but he thought it certain that since it was now proved that one animal may live with the blood of another, 'those animals that want blood or have corrupt blood may be supplied from others with a sufficient quantity and of such as is good.'

When it is remembered that most diseases were believed to be due to the malevolence of the humours entering the blood, it is not surprising that this demonstration of possible replacement by transfusion should have made a great stir in the medical world, and that the earlier numbers of the Philosophical Tracts of the Royal Society should contain many communications relating to this subject.

Lower had transfused from the artery of one animal into the vein of another, but Dr. King modified the method in 1667 by the safer plan of transfusing from vein to vein, using for this purpose a sheep, which he said did not appear 'at all concerned at the end of the experiment', indeed 'we keep this sheep alive, she being sent to grass again and seeming hitherto very strong and lusty'. In the same year Monsieur Denis, Professor of Philosophy and Mathematics at Paris, performed similar experiments in France, and also a certain Monsieur Gayant, who asserted that on transfusing the blood of a lusty young animal into an old decrepit one, the latter 'two hours after did leap and frisk whereas he was almost blind with age and could hardly stir before'. The matter now gave rise to an international dispute as to priority which attained such dimensions that, first in May 1667, and at more length in October 1667, the Royal Society published 'a vindication of this Invention from Usurpers', which I venture to quote, as showing the importance attached to Lower's experiment.

'We are obliged', say the Publishers of the Philosophical Tracts, 'to remove a mistake found in one of the late French journals affirming with confidence that 'tis certain the French have given the English the first thought or notion of the experiment. And why? Because, say they, there are witnesses that a Benedictine Fryer, one Don Robett de Gabets, discoursed of it at M. de Monmours, ten years ago. 'Tis notorious that, at least six years since, the learned and ingenious Dr. Christopher Wren did propose to the University of Oxford (where he is now the worthy Savilian Professor of Astromony, and where very many curious persons are ready to attest this relation) that he thought he could easily contrive a way to conveigh any liquid thing immediately into the mass of the blood. This proposition being made, Mr. Boyle injected opium (through a quill into a vein) stupefying an animal. This hint was enough for the Royal Society, some while after, to advance Infusion into Transfusion for the trial of which they gave order at their publick meeting of May 17, 1665. The tryals proving then lame for want of a fit opportunity and a well contrived method of operation, the learned Physician and expert anatomist, Dr. Lower, since found out such a method which is published in number 20 of these transactions before which time it had been already practised by the said Doctor in Oxford.'

This account is somewhat misleading, since it conveys the impression that the Royal Society was the real source of Lower's invention; priority claims are, however, selfish exhibitions as the Royal Society seems to have felt, and a concluding sentence is framed with a more just regard to the real interests of science.

'But whoever the Parent be, that is not so material as all that lay claim to this Child should joyn together their efforts and cares to breed it up for the service and relief of human life, if it be capable of it; and this is the main thing aimed at and sollicited in this *Discourse*.'

In accordance with this sound advice transfusion experiments proceeded, and were soon carried out on human subjects. For instance, on November 23, 1667, transfusion was practised in a medical case on one Mr. Arthur Coga at Arundel House, London, in the presence of 'considerable and intelligent persons', by Dr. Lower and Dr. King, the blood of the sheep being used. Their report states that 'the man after this operation as well as in it found himself very well, and hath given his own Narrative under his own hand enlarging more upon the benefit he thinks he hath received by it than we think fit to own to as yet. He also urgeth us to have the experiment repeated upon him.'

In 1669, at the age of thirty-eight, Lower published a remarkable book written in Latin, and dedicated to Dr. Thomas Millington. It is entitled *Tractatus de Corde; item de Motu et Colore Sanguinis*, and deals with some of the most fundamental problems in physiology.

Accepting Harvey's demonstration of the circulation, he describes in detail the structure of the heart and the course of its muscular fibres as revealed by his own dissections. He then goes on to show the absurdity of the prevalent view that the motion of the heart is bound up with the effervescence of its contained blood, for as he points out the heart wall is made up of muscle, and like all other muscle is able to contract, and since general muscular contraction is not due to an incension in the mass of the blood, but is the peculiar property of the muscle and its supplied nerves, so the motion of the muscular heart must be due to such a contraction property.

One of Lower's proofs that the heart's movement was dependent upon nerves going to heart muscle, was the effect of ligaturing the eighth pair of cranial nerves now called the vagus. He noticed that after this the motions of the heart became irregular and feeble; hence he concluded that they were dependent on a nervous flow to the heart muscle. As a matter of fact it was not until 1845, nearly two centuries later, that the brothers Weber, repeating Lower's experiment, showed that the vagus nerves were excited by such ligatures, and that the nervous impulse thus aroused inhibited the heart's activity.

Another part of the treatise deals with the colour of the blood; he noted the difference in colour between arterial and venous blood, and then infers that this is related to the transit of the blood through the lungs, since the colour is dusky in the blood going to the lungs and bright red in that coming away from these organs. Some of his experiments on this subject possess a special interest, because they attracted the attention of the thoughtful young Mayow who witnessed them.

Thus he observed that in animals killed by suffocation the colour of the blood was very dark, but that even in such an animal the bright red hue could be reproduced if air was blown through the lungs, and since in this case the respiratory movements were absent, the presence of air alone was responsible for the change of hue. He also noticed that the clot formed in shed blood became bright red on the surface; this must, he said, be due to the air, since when cut open the interior was dark in hue, yet being now exposed to the air it shortly became also bright red. From such observations Lower concluded that the object of respiration was to bring air near the blood, and thereby make it fit for the heart and other organs, this fitness being indicated by its becoming bright red.

Lower's treatise contains a full description of his demonstration of transfusion, and an account of the possibilities thus opened up. Among the transfusion experiments is one referred to by Mayow who evidently witnessed it, for Mayow says that he was greatly impressed by noticing that the animal 'when transfused with bright blood scarcely found it necessary to draw his breath at all, although before he had been breathing deeply and panting'.

The extent of Lower's recognition of the real significance of respiration is displayed by the language he uses in a notice on the subject published in the Philosophical Tracts; 'We may therefore conclude', says he, 'that the blood in its passage through the lungs absorbs air, to which absorption its bright red colour is owing,' and he goes on to remark that 'afterwards, however, when the air has escaped from the blood into the structure of the system and parenchyma of the viscera, it is perfectly agreeable with reason to say that the venous blood being deprived of it appears on this account more dusky and black'.

The whole of Lower's *tractatus* is a small octavo volume of some 200 pages, and contains, besides the facts and conclusions just referred to, a large number of other important physiological observations. Such for instance are, his descriptions of transfusion, of the flow of chyle, and of the anatomy of the thoracic duct, through which the chyle reaching the blood 'serveth for the nourishment of the several parts of the body', his demonstration that dropsy is an exudation from the blood, and may be produced in an animal by compressing the larger veins, and his inference from injections that both arteries and veins must end in fine hair-like branching tubes which, in any given organ, must freely communicate by innumerable branching capillaries too fine to be seen by the eye.

There is no question that Lower should be placed in the highest rank of experimental physiologists, nor can it be doubted that the facts, which he so ably and convincingly demonstrated, were the starting-point for the great conceptions which Mayow was now to formulate. Lower proved that respiration was a means of taking air into the blood, Mayow was to show what part of the air was taken in by respiration, but being a thoughtful student of a distinctly philosophic bent, Mayow carried his studies much further, and surpassed Lower and all his contemporaries in the large scope of his scientific conceptions.

The opening chapter of Mayow's monumental treatise (The *Tractatus Quinque*) deals with nitre, as to which he remarks that though many authors had written 'as if it had been ordained that *nitre* should make as much noise in philosophy as in war, yet the properties are still concealed from our knowledge'.[1] He then shows that nitre (potassium nitrate) can be separated by distillation into two parts, one acid, the other earthy; and that, by adding the acid part to the earthy one, nitre can be reformed. The nitrous acid part corroded metals and evidently contained some peculiarly potent body. Nitre itself when mixed with sulphur produced the violently combustible substance gunpowder, and Mayow affirmed that it was the nitrous part of the nitre which was the really potent element in this explosive. This formed the starting-point for a whole series of experiments on air, along lines carried on, independently, by Boyle. He utilized, for these, inverted jars placed over water, the now familiar pneumatic trough; in these inverted jars he imprisoned combustible substances, small animals, and burning flames, and he observed that in the last two cases the extinction both of flame and life was associated with a

[1] See Note H.

diminution by one-fourteenth or more of the volume of the contained air, moreover the air lost weight by giving up this constituent which was essential both for the production of flame and for the sustenance of life. He proved this by a number of convincing and beautiful experiments, only two of which need be described now. Taking a substance which could easily be ignited when the sun's rays were focussed upon it through a lens, he placed this in an inverted jar under the pneumatic trough. If the air in this jar had previously been diminished in volume by a burning flame, he found that the substance would not flame or burn, although the sun's rays were focussed on it. The second experiment was still more remarkable. He calcined a known weight of antimony by placing it in the focus of his lens, and, observing that it behaved as if nitrous acid had been poured upon it, he carefully weighed the calcined mass, when he found that it had not diminished, but had actually increased in weight. Can we, says he, conceive whence that increase of weight is derived, except from the fixation of something in the air? This something in the air, he said, must be its more active and subtle parts. He first termed these the igneo-aerial or fire-air particles, but subsequently the nitro-aerial spirit or vapour, in short what Lavoisier afterwards rediscovered and named oxygen gas. Air was shown to contain a special 'nitro-aerial' constituent, which could be taken in and fixed by what, in the limited chemical jargon of the day, were termed the salino-sulphureous combinations of matter. Mayow's discovery was far more than the disclosure of a fact, it carried with it a whole world of new conceptions, for the importance of this air constituent, both to inanimate and to animate things, was revealed to his mental vision. To truly interpret experimental results, to confirm this interpretation by definite and novel contrivances, to realize the essence of the interpretation, disregarding its accidental trappings, and then to sweep in thought from the facts to great conceptions, all these, and particularly the last, are the marks of genius; they stamp Mayow as one of the greatest of scientific men. It has been a matter of surprise that this achievement should have been accomplished by a young man barely twenty-four years of age, but this is by no means exceptional. Newton invented the calculus when little more than twenty, and had grasped the idea of gravitation before he was many years older; Black at twenty-four discovered carbonic acid; R. Mayer formulated the law of the conservation of energy when twenty-six years of age; many other such instances are to be found in science, letters, fine art, and music. Professor Tigerstedt of Helsingfors, having compiled many such instances, has brought them forward to illustrate the physiological contention that it needs a certain youthful plasticity of cerebral structure for those original productions of the mind which we term the creations of genius.

Let me now give you some idea of the width of Mayow's scientific conceptions, commencing with the more strictly chemical ones. Whence, says he, does nitre derive its potency? From the nitrous acid which went to form it. And whence does this acid derive its potency? From the nitro-aerial particles of the air which it has taken up and fixed. Why do substances burn in air? Because they take in and fix to some of their parts these nitro-aerial particles. What is flame? It is the chemical union of such nitro-aerial particles with the more volatile salino-sulphureous ones. What, indeed, is chemical heat but this very fixation? Why then do substances like gunpowder burn even in a vacuum? Because they have already got the essential air constituent, the nitro-aerial particles being in the nitre. Mayow's account of the formation of acids and of oxides is in all essentials that elaborated a century later by Lavoisier. Sulphur, he says, has no acid properties, but if burnt, then its fixation of the nitro-aerial particles, which constitutes this burning, confers upon it the acid properties. His description of the formation of vitriol from Iron Sulphide by burning is modern in its general characters. The rusting of iron in air was in his view the fixation of nitro-aerial particles by the surface parts of the iron, and in a similar way other metals could fix these particles, forming metallic nitro-aerial compounds; he had thus grasped Lavoisier's conception of oxides.

But to realize the full extent of his genius, consider his views upon the relation of this newly discovered aerial constituent to the organic world. Mayow's mind never rested content with a single set of facts, it was his ruling passion to get at general or elementary principles. Having observed that this nitro-aerial constituent of the air was necessary for the souring of wine, and that as 'iron besmeared with oil is not corroded by rust' so 'flesh covered with butter is kept long from putrefaction', he thought it probable that both the fermentation and the putrefaction processes were dependent upon a supply of nitro-aerial particles; he could not possibly suspect what modern microscopic methods alone have demonstrated, that the potent agents in the air for these processes were minute micro-organisms floating in it.

But although in this instance the real cause of the observed changes was hidden from him, it was far otherwise with some of the fundamental body functions, for as regards the real significance both of respiration and of what we now call the bodily metabolism, his conceptions are astonishing, both from their modern character and from their intellectual breadth.

Starting with the fundamental fact that something was taken from the air by the respiration of the animals, and that this something was the nitro-aerial constituent, he saw that the intake, not of air but of this constituent, was the necessity for life; a relatively small part of the air, his nitro-aerial particles (Lavoisier's oxygen), formed its potent part, and whilst the great bulk of the air had no relationship to animal life, this one portion was as fundamental for life as for combustion. And why? Because there was a process resembling combustion continually going on in the body tissues, as evidenced by the animal heat. Hence this combustion within the body being nothing but the fixation of nitro-aerial particles by the salino-sulphureous compounds in the tissues, there must be during life a continuous drain on these particles, which being thus continually used up, must be continually renewed by taking them in afresh from the air. This was, therefore, the enigma of respiration, and, realizing this, he swept aside all those views which I have referred to as prevailing among his contemporaries. As to the mysterious vital flame supposed to emerge in the heart, it was a myth, the body heat being a true combustion due to the fixation of nitro-aerial particles, and from no other source than air could the immense drain upon these particles be supplied. Two supplies were necessary for animal life; one of these was that of the combustible material consisting of appropriate salino-sulphureous compounds, but since these when taken in by the food were elaborated and stored in the body tissues, their waste could be made good by meals occurring at comparatively long intervals;

not so the other supply of nitro-aerial particles, which being not stored but continually fixed by this combustible material, had to be renewed every few seconds by respiration. Thus it came about that deprivation of food did not cause rapid death but slow wasting, the body giving up its salino-sulphureous stores, such for instance as fat, whilst deprivation of air, and thus of nitro-aerial particles, could not be endured for even a brief space. But how did these nitro-aerial particles pass from the lungs to the body tissues. In the light afforded by Lower's experiments, Mayow justly inferred that in the lungs the nitro-aerial particles were first fixed feebly by the colouring matter of the blood, such fixation making this colour bright red; in this form they were carried by the blood stream to the tissues, where they left the blood to unite eventually with the combustible salino-sulphureous compounds.

Finally, where was the main store of these combustible compounds and the chief seat of that fixation or combustion which produced the body heat? With the prescience of genius Mayow concluded that it must be in the muscles, since all muscular movement increased the production of heat, diminished the stores of fat, and necessitated a larger supply of nitro-aerial particles, as evidenced by its causing hurried and strenuous respiration. This is the foundation fact of what is now termed by physiologists the body metabolism, that is the cycle of chemical change which occurs in the whole organism. It remained unappreciated for two centuries.

In 1796, Von Madai, who like Mayow died young, enunciated the conception that the forces released in muscular contraction were due to the oxidation of carbon compounds, but in spite of Humboldt's approval, this view obtained no credence. Two centuries after

Mayow, in 1845, Helmholtz demonstrated that muscular contraction was associated with the formation of oxidized carbon compounds and with the production of heat, whilst Joule then showed that this muscular development of heat accounted for three-fourths of the total heat of the body. In a treatise upon muscular activity written by Heidenhain in 1864, reference is made to Mayow in these terms: 'It is truly astonishing how many important physiological discoveries are contained in Mayow's *Tractatus Quinque*.'

There are naturally some doubtful conceptions in Mayow's great book; such are his views as to the nervous activities.[1] His intense desire to divest all physiological phenomena of any occult or mystic meaning led him to favour some hypothesis which should replace nerve-spirits by something definite; this something was in his view nitro-aerial particles.

Since nerves form the essential paths to muscles he elaborated the view that the necessary nitro-aerial particles reached the muscles, not merely by the blood, but by this more subtle channel. He believed that they were especially taken from the blood by the brain and other large appendages of the nervous system, and that they flowed from these central masses down the nerves to the muscles as nervous impulses; on reaching the muscles fixation occurred and thus heat-production and muscular contraction ensued. In this way he accounted for the obvious relationship between the nervous system and the occurrence of the body movements. Although this view is erroneous yet it is clear that the real significance of respiration in its relation to the production of the body heat had been revealed to

[1] It is interesting that the latest conception of central nervous activity is the release of stored intramolecular oxygen (Verworn).

Mayow, and this is confirmed by his just conception of that early stage of man's existence in which the respiratory movements do not occur. The third portion of his celebrated treatise deals with the conditions in this foetal stage; here he is quite explicit and astonishingly modern. He asserts that the nitro-aerial supply of the foetus must be provided by the respiration of the mother, and that these necessary nitro-aerial particles enter the blood of the foetus from the maternal part of the uterine wall, and thus furnish the non-breathing foetus with this essential ingredient of its life, whilst, in a manner precisely similar, the foetus receives its supply of salino-sulphureous food from the maternal stores.

The precision of Mayow's details is as remarkable as the scope of his conceptions. Perhaps the most conspicuous example of this precision is the account which he gives of the muscular mechanism of respiration. He describes how the diaphragm and intercostal muscles must by their contraction make the thorax larger, the former because it descends, the latter because they raise the sloping arches of the ribs which he showed to be pivoted on joints both in front and behind, and he demonstrated by the pneumatic trough that, if this enlargement occurs, then the elastic lungs must themselves enlarge, sucking in more air. The whole account is almost in detail that given in modern textbooks of physiology, whilst his demonstrations are the familiar ones still used for illustrating the mechanical features of the respiratory mechanism.

What, it may be asked, did Mayow fail to realize as regards Respiration apart from the nervous aspects of the problem? The most important omission in his work was his failure to recognize that the whole process involved not only the taking in of that special aerial constituent which he had discovered, but also the giving out to the air of another special compound derived from the body tissues. This constituent, a compound of Mayow's nitro-aerial particles with carbon, carbonic acid gas, was not discovered until 1752, and was then called by its discoverer, Black, 'fixed air'.[1]

The astonishment which is produced in our minds by Mayow's extraordinary scientific achievements is only equalled by the undoubted fact that in spite of what appears to us to be the lucidity of his presentation, his work caused no conviction in the minds of his contemporaries and was disregarded for more than a century.

Even when Priestly in 1774, and Lavoisier in 1775, by the discovery of Oxygen placed Chemistry on its modern basis, Mayow's previous work on this subject was still unrecognized, and the first person to draw attention to it was Dr. Beddoes in a book printed at Oxford in 1790, entitled, *Chemical Experiments and Opinions extracted from a work published in the last century.* This was followed in 1798 by a more detailed account of Mayow's work by Dr. Yeats entitled *Observations on the Claims of the Moderns to some discoveries in Chemistry and Physiology.* The overwhelming effect which the perusal of Mayow's original treatise produced on the minds of these two gentlemen will be best appreciated by taking a few out of the many laudatory sentences in which they raise what they call 'a slender monument to neglected genius'. Thus, to quote Dr. Beddoes first, his astonishment at the modern character of some of Mayow's experiments is shown by the following passage in a letter to his friend Dr. Goodwyn:—

'Should I ask you, who of all your acquaintance is the person least likely to be overtaken by surprise, you

[1] See Note I.

would, I think, name a certain northern professor to whom you and I may have our obligations; yet at sight of the annexed representation of Mayow's pneumatic apparatus this sedate professor lifted up his hands in complete astonishment.'

Other passages display his unbounded admiration for Mayow's intellectual insight. 'Consider,' says Beddoes, 'the quantity or mass of truth which Mayow surely detected *per sua pericula suasque meditationes*, and then name among his predecessors or contemporaries a rival fitted to contend with him for the palm of philosophy.'

Further on he places Mayow on the same pedestal of scientific fame as mankind had already placed Newton: this is brought out in the following passage:—

'Newton's discoveries concerning light, I cannot help fancying, stand in the same predicament with Mayow's on air; to me both exhibit themselves as the greatest deviations presented by the whole history of science from the ordinary and natural progress of knowledge.'

With just pride Beddoes concludes by saying:—

'I flatter myself that henceforward Mayow will share the glory of Verulam and Newton and be named with due respect by all, especially by those who have ever looked into his works.'

Yeats is equally enthusiastic in his appreciation of Mayow's greatness, nor can he avoid a slight hit at Beddoes, whose description bears in his opinion marks of being hastily done. Thus, according to Yeats, the account given by Beddoes is inadequate 'because his professional as well as other important avocations hurried him too much in detailing the beauties of Mayow; and indeed' (says Yeats) 'the ingenious Dr. Beddoes, with a candour and liberality peculiar to himself, has written me that he is sensible his extracts from Mayow have been published in a cursory manner.'

There is a fine passage in the preface written by Yeats, which, as it gives a graphic picture of the work of unrecognized genius, may be appropriately quoted:—

'With what coolness (says Yeats) were the beautiful experiments of Mayow received upon their publication. Retired from the world, he planned and executed in the cloisters of a college experiments the most elegant and decisive that the greatest genius could contrive. Unassisted by the labours of others, not encouraged by the adoption of his opinions, his aspiring genius soared into the regions of truth amid the obstacles of surrounding opposition. Every one who is acquainted with Mayow's writings and the spirit of his expressions must acknowledge with regret that his early death was a great loss to science.'

Yeats goes on to show the special reasons which made Mayow's early death such a heavy loss; it was essential that the author of such novel conceptions should live to explain their meaning to his contemporaries; as it was, however, they fell on barren soil, for even the terms he used were misunderstood, and his ideas, according to Yeats, 'perplexed because they were not properly studied, his doctrines were neglected because at that time severe attention was necessary to understand them'. But all this alone can scarcely account for the complete disregard of over a century. The *Tractatus Quinque* was no light hid under a bushel; it was published by a celebrated University, and reprinted in Holland, Germany, and France.

Nor can it be asserted that Mayow, being a man born out of due time, was so far ahead of his age that all his contemporaries and immediate successors were intellectually incapable of grasping the significance of his discoveries. It is ridiculous to suppose that such men as Newton and Boyle were incapable of giving that severe attention to which Yeats alludes, yet the fact remains that both Newton and Boyle wrote as if they were ignorant of Mayow's work. As it stands, therefore, the want of recognition accorded to Mayow is most surprising, and no adequate explanation has, so far as I know, been advanced. I venture to throw a side-light upon the matter derived from a circumstance which has come to my knowledge during the perusal of the early Tracts of the Royal Society. These early publications of what are now known as *The Philosophical Transactions*, were greatly influenced by Hooke, an ingenious natural philosopher but a self-opiniated man. Hooke was Curator of the Royal Society and as such is believed to have been the author of the numerous abstracts of notable scientific treatises, which were published in the Tracts for the information of the Fellows.

Such an abstract of Mayow's first work appeared in the Transactions of November 16, 1668. In this it is stated quite correctly that Mayow affirmed that 'there is something in the Air absolutely necessary to life, which is conveyed into the Blood, which, whatever it be, being exhausted, the rest of the Air is made useless and no more fit for Respiration'. But the abstract goes on to diminish the significance of this by such misleading language as the following. 'And enquiring what that may be in the air so necessary to life, he (Mayow) conjectures that it is the more subtile and nitrous particles the air abounds with'. Here is the first misapprehension, for Mayow does not use the term 'nitrous', but 'nitro-aerial, or 'igneo-aerial', in order to convey the idea that although the particles in the air exhibited some of the properties of nitre, their real significance lay in their being associated with combustion. Immediately following this misapprehension, a whole series of mistakes occurs in the abstract, which goes on to say, 'this aerial nitre he makes necessary to all life, and considering what part this nitrous air acts, he is of opinion that this nitre mixt with the sulphureous parts of the blood causeth a due fermentation'. Thus the author of the abstract now leads his readers to believe that Mayow's conception was that the air contained the well-known substance called nitre, and that the intake of this nitre, by mixing with the sulphureous matter of the blood, produced a combustible mixture presumably like that of gunpowder.

The writer of the abstract then professes to give the pith of Mayow's physiological views in terms which Mayow himself would scarcely recognize, such, for instance, is the statement that the fermentation raised by the mixture of the nitre taken in with the sulphur of the blood is one 'which he (Mayow) will have raised not only in the Heart alone, but immediately in the Pulmonary vessels, and afterwards in the arteries no less than in the Heart'.

All this is a mere travesty of Mayow's great work, and must have seemed meaningless to the intellects of men like Boyle. Nor is the misstatement rectified by the later and more lengthy account of the *Tractatus Quinque* given in the Philosophical Tract of July 20, 1674, by the same hand, since in this the writer dismisses respiration by saying that of this 'we have given an account in number 70 of the Tracts, so that for fear of being too prolix we must say no more here'. Nevertheless, this second abstract does put forward a more intelligent account of Mayow's purely chemical conceptions, although it considers Mayow's views on combustion to be quite fanciful, since as regards the explication of the nature of fire the author (Mayow) 'makes its form and essence to depend upon the said nitro-aerial spirit put into motion; rejecting the opinion of those that will have Fire producible by the subtle and briskly moved parts of any matter, and declaring on this occasion his dissent from those philosophers that deduce all effects of nature from the same uniform matter'. In a side-note the writer of the abstract then states: 'compare herewith the considerations of the noble R. Boyle about the excellency and grounds of the mechanical hypothesis'. Mayow's rejection of the Flamma vitalis emerging from the heart is said to be advanced in a manner calculated to provoke 'the maintainers thereof to a vindication', and his great conception of the muscular metabolism producing animal heat is regarded as a mere 'hypothesis about the nature of animal spirits'. In the course of the abstract the writer shows his animus against the whole treatise by such statements as 'so much, if not too much, of the first treatise', and abruptly concludes his description with the sentence, 'but apprehending we have already been too tedious in giving this account, we must here break off'. Now it is probable that the abstracts published by the Royal Society in their Philosophical Tracts would give the Fellows of the Society the readiest information as to the character of any separately published treatise, particularly when this was written, as Mayow's was, in Latin. If so, then it is not extraordinary that but little attention was paid to Mayow, for the abstracts set forth his conceptions in such a crude way and in language so imbued with the traditional errors of the age, that they could not fail to produce an unfavourable impression upon the more acute intellects.

Why the mistakes were not corrected we have no means of ascertaining. It must, however, be remembered that Mayow was not a Fellow of the Royal Society at this time, and it is quite possible that he never saw the early numbers of its tracts; moreover, as he died a few months after being made a Fellow for his analysis of the Bath waters, but little opportunity for explanation was afforded him. The only person who might after Mayow's death have shown the misleading character of this account was Lower, but Lower was himself in bad odour through his Whig tendencies, and finally left London for Cornwall. Whether all this may or may not account for the complete disregard of Mayow, the mere fact that such abstracts were furnished by the chief scientific society of the day, is a most significant circumstance, and indicates that whoever wrote them did not realize the paramount necessity of reading new work, such as Mayow's, with an intelligent mind, free from traditional bias and open to the reception of novel ideas. But at least his successors might, one would imagine, have been able to grasp the significance of Mayow's great conceptions. Here there came in other opposing influences, and in particular the enormous authority wielded by Stahl, who was born in 1660 and died in 1734. He was Professor of Medicine at Halle, and successively Court Physician at Weimar and Berlin, and being in many respects a really great chemist, his ideas ruled paramount in this subject for the greater part of the eighteenth century. But, according to Stahl, combustion was due to the circumstance that combustible substances contained a theoretical element, phlogiston; when burnt this substance left them, and they were dephlogisticated. This is the old traditional view of combustion decked out in a new garb; its universal acceptance made all recognition of Mayow's conceptions impossible, for the two were quite irreconcilable. The phlogiston theory of the great Stahl became the gospel of the eighteenth-century chemists, until there arose men who, like Mayow, rent the traditional veil of meaningless hypothesis, and, freed from its bondage, fixed their mental vision towards the same wide field that Mayow had beheld a century before. The whole story furnishes one of the most striking illustrations which the history of science affords, of the great truth that in the slow progress of mankind towards the elucidation of natural phenomena, by rendering these more capable of rational causative explanation, the minds of men in successive generations do not ascend by straight paths towards the summit of the hill of knowledge; they climb painfully up spiral tracks so that the mental vision as it mounts often looks back, and then gazes forwards towards the same point of the compass that it did years before, yet is this later outlook a different one, being made from a higher plane and commanding in consequence a wider horizon.

If this imperfect account of Lower and Mayow serves merely to enforce this single truth, then my choice of subject will be more or less justified. But I do not feel the necessity for any such justification, for I am confident that the study of the lives and works of our predecessors is as imperative for scientific men as it is for historians, whilst the duty of undertaking it receives an additional sanction when, as in the case of Lower and Mayow, their deeds lie buried with their bones in tombs which have been suffered, through neglect, to fall into decay.

It is my hope that this effort of mine to clear away the dust which has for so long obscured the names of these two great pioneers in physiological science may enable some to read more clearly the record of their past achievements, and thus receive instruction from their example and incitement from their renown.

NOTES

NOTE A. Peter Sthael is described in Wood's diary as 'the noted chemist and Rosicrucian of Strasburg in Royal Prussia, a Lutheran, a great hater of women and a very useful man'. Wood attended his classes. See *Life and Times* of Wood, by A. Clark (Oxford University Press).

NOTE B. There are frequent references to Lower in Wood's diary. Wood and Lower seem to have been close friends and frequent companions at both cookshop and tavern.

NOTE C. According to Foster's *Alumni Oxonienses* Mayow took the degree of D.C.L.; but in the title-page of the celebrated *Tractatus Quinque* Mayow is described as LL.D. and Medicus. The *Tractatus* was published by the University.

NOTE D. The portrait is reproduced in the frontispiece to this pamphlet.

NOTE E. This information is one of the two references to Mayow in Wood's diary. The other reference is as follows: 'Mr. Mayow of Allsoules College being returned from a journey Mr. Prestwich (a notable punner) met him and said, "Oh, Mr. Mayowmet". Asked why he called him so, "Because" saith he "Mr. Mayow is well met".' Wood's comment is 'verie ridiculous'. Neither Evelyn nor Pepys mention Mayow.

NOTE F. 'To Westminster to Dr. Turberville about my eyes, whom I met with; and he did discourse, I thought, learnedly about them; and takes time before he did prescribe me anything, to think of it'. Pepys, *Diary*, June 23, 1668.

NOTE G. There seems to be some foundation for the opinion that Lower's friend Wood regarded Willis as prone to take the credit of Lower's discoveries. The following passage occurs in Wood's diary: 'in this month of May, Mr. Richard Lower of Christ Church discovered the healing well in Northamptonshire near King's Sutton, who, showing it to Dr. (Thomas) Willis, afterwards, who commended the water to divers men there, it is now reported that the said Dr. Willis was the first finder thereof.' Wood's *Life and Times* (by A. Clark).

NOTE H. The full title of Mayow's remarkable work runs as follows: 'Tractatus Quinque Medico-physici. Quorum primus agit de Sal-nitro et Spiritu nitro-aereo. Secundus de Respiratione. Tertius de Respiratione Foetus in utero et ovo. Quartus de motu musculari et spiritibus animalibus. Ultimus de Rhachitide. Studio Joh. Mayow. LL.D. & Medici. Nec non Coll. Omn. Anim. in Univ. Oxon. Socii. Oxonii, e Theatro Sheldoniano. An. Dom. M.DCLXXIV.'

NOTE I. Black, like all his contemporaries, was quite ignorant of Mayow's work. To him air was an entity, homogeneous and possessing specific although unknown characters. He thought that it was taken in and fixed by burning carbon, hence his term 'fixed air' for what was subsequently found to be carbonic acid gas.