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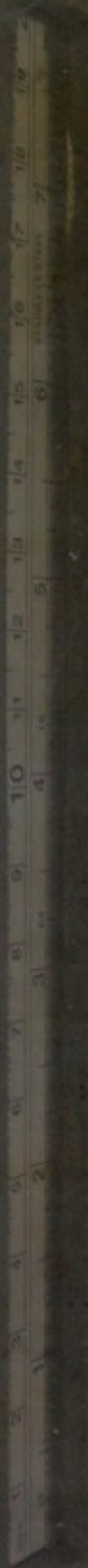
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MAY, 1902.

*The Rise of the Experimental  
Method in Oxford*

BEING THE

NINTH ROBERT BOYLE LECTURE

DELIVERED BEFORE THE

OXFORD UNIVERSITY JUNIOR SCIENTIFIC CLUB

On May 13, 1902

BY

PROFESSOR CLIFFORD ALLBUTT, M.D., F.R.S.

LONDON: HENRY FROWDE, AMEN CORNER, E.C.

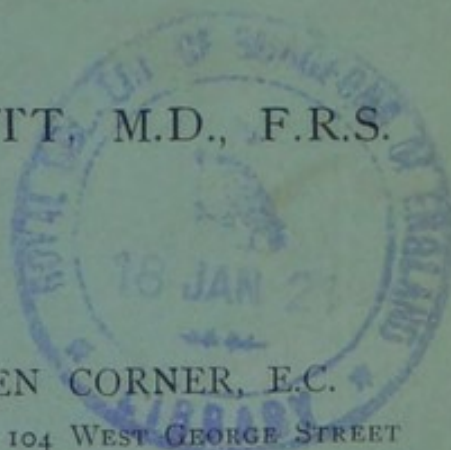
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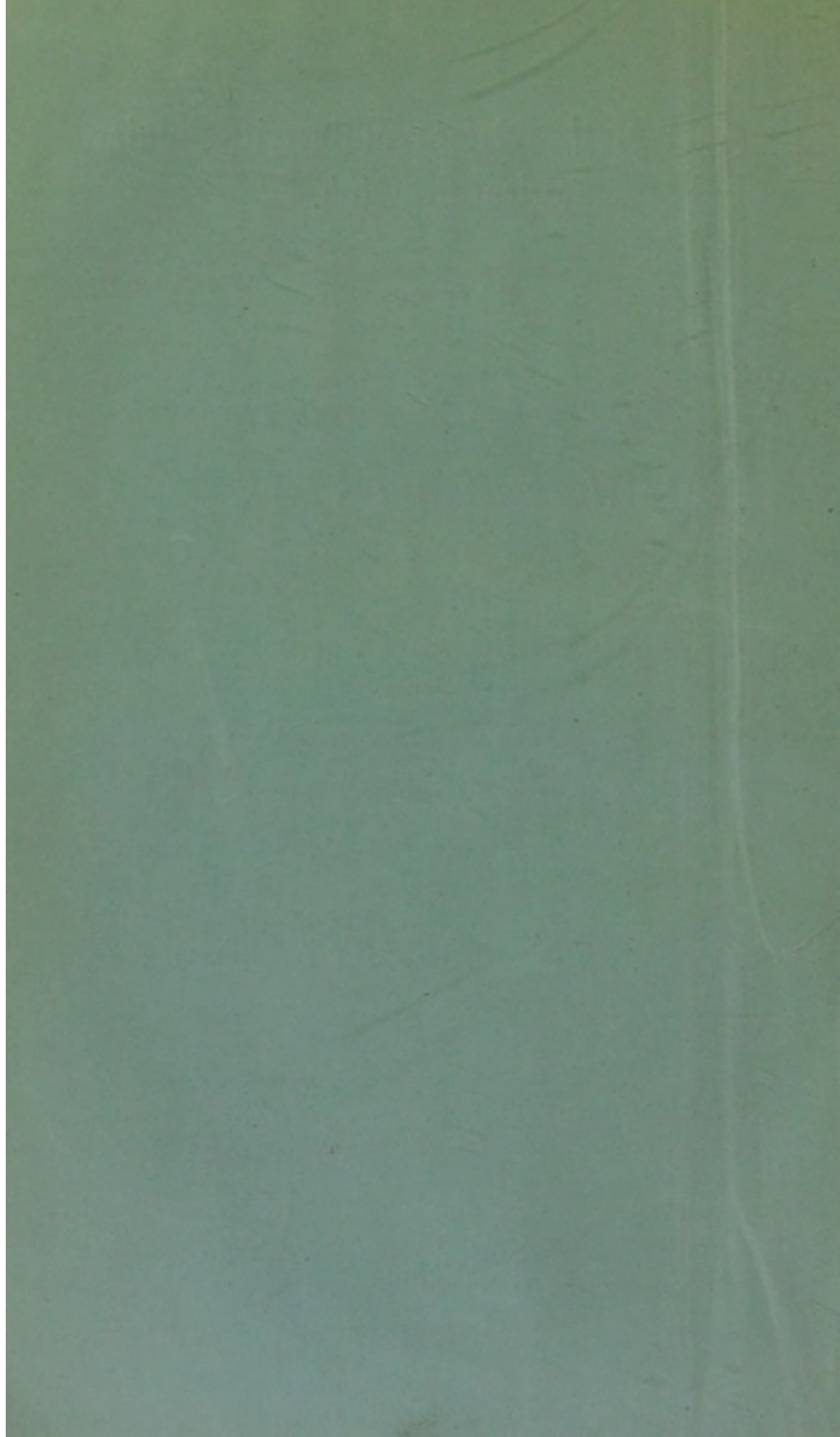
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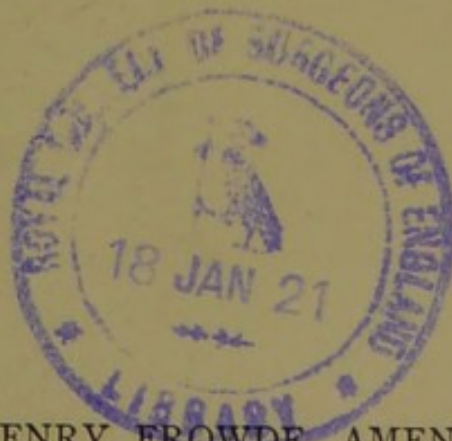
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## The Rise of the Experimental Method in Oxford.

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IN this age of steam cars, of steam ships, and of steam balloons, the mobility of the European people in the Middle Ages is still marvellous to us. We try to picture to ourselves knights, troubadours, pilgrims, merchants, friars, scholars driven by demons of unrest about an unparcelled world; and of this medley scholars were perhaps the most vagabond. 'O curiosi ingegni, Peregrinate al mondo, cercate tutti i numerosi regni.' As Petrarch said of them, 'Agitatione mentis et corporis ignorantiam discussuri,' they swept in flocks, like birds in their migrations, from school to school; having no country but in the several quarters or 'nations' where they were gathered together; for the European nations in our sense did not exist. During the five centuries after the Conquest the realms of Italy, Burgundy, France, England, and the Empire were variables as inconstant as their peoples; what we now call a university was then no particular spot on the earth but, like the Ark in the wilderness, moved whithersoever a great teacher, such as Fulbert, Lanfranc, the Anselms, Abélard, or Peter Lombard, unfurled his standard. This mobility was indeed the guarantee of the freedom and the power of learning. Not till the fourteenth century did the 'ius ubique docendi' come to dependence on charter from pope, king, or bishop; till then the scholar owed no



vassalage. Chartres was no more a French school, in the modern sense, than Oxford an English one ; Alcuin, Sershall, John of Salisbury, or Alexander Hales were Englishmen chiefly in the accident of birth. Gradually, however, by tillage, by the invention of printing, by the difference of tongues, and by the hammering out of national boundaries, folk became attached to the soil, and the means of culture were brought within the reach of those who dwelt at home.

But this change came about very slowly ; while at no time was adventure more ardent than in the sixteenth century, yet the printing press of Gering and Rembolt was in safe keeping within the precincts of the Sorbonne, whose censure, in spite of the favour to letters of Louis XI and Francis I, was tenaciously and inquisitorially exercised in regard of the sale as well as of the publication of books. In England, under the harsh rule of the Starchamber, very few presses were licensed ; to Oxford and Cambridge were allowed but one press each, and between the Archbishops and the Stationers' Company even these two had a bad time. Indeed in the sixteenth century, unless at Wittenberg or Basel, freedom of speech was more closely stifled than in the time of Abélard. In the sixteenth century Ramus, ejected from Paris, was repulsed even at Genoa ; in Italy the naturalists of Cosenza and Naples could not prevail against Aristotle ; and Bruno, who fought Aristotle lyrically and allegorically rather than scientifically, was burned for his pains. One may go to the stake for error as well as for truth ; but, as Voltaire said, ' Il faut avouer qu'on brûle quelquefois les gens un peu légèrement.' It was not until the day of Descartes and Gassendi that the *'Αριστοτελουμαχία* was virtually decided ;



and that the Accademia del Cimento, the Lincei, the Royal Society, and the Academy of Sciences in Paris took possession of the debated territory, and converted the hierarchical ferocity of the sixteenth century into the culture and humanity of the seventeenth.

'Till a man is sure that he is infallible it is not fit for him to be unalterable,' said Boyle; and well may we wonder to see the weight of the yoke, not of the Aristotle of Melanchthon, but of the scholastic Aristotle, imposed for three centuries on the faithful as the final form of infinite truth. Herein even Calvin was docile, and favoured the inculcation of academic peripateticism. I say we may wonder; for we have but to carry our memories back to Philip Augustus to see, in 1209, that the 'Civitas Philosophorum,' as St. Thomas called Paris, was engaged in burning all works imputed to the Stagyrite. The *Metaphysics* of Aristotle appeared in Paris about the beginning of the thirteenth century (Launoy, *De var. Arist. fortun.*); in August, 1215, the teaching of the *Metaphysics*, and of the *Physics* also, was forbidden in Paris under pain of excommunication<sup>1</sup>. This, and other outrages, chiefly by the masterful hand of Blanche of Castile, on the 'Lehrfreiheit' of Paris—then the university not of a fragment of modern France, but of Western Europe—at the time when the culture of the first renaissance was streaming into Europe from the Arabian sources, drove its scholars abroad; and, begging their way from gate to gate, long flights of them came to the comparatively unknown

<sup>1</sup> In the library at Douai (Cousin, *J. des Savants*, August, 1848) is a MS. of Roger Bacon on Aristotle's *Physics* and *Metaphysics* in heavily corrected writing of the fourteenth century, and entitled 'Rogerius Bacon, ordinis Minorum, de rebus physicis, monasterii Sancti Petri Corbigensis,' a curious sidelight on Bacon's troubles in Paris.



schools of Oxford and Cambridge. These Universities arose not in coastward ports and towns, such as London, Colchester, Lynn, or even Lincoln, great school as it was in the thirteenth century ; nor again in upland cities such as Winchester ; but under the shadow of fortresses commanding the head waters of eastward rivers where, while access to the outer world was easy, traffic penetrated far inland. Oxford was a great political city, often a royal residence ; its trade was extensive and, as things went, peaceful : Cambridge commanded the gates of Mercia, and its fair (Stourbridge), confirmed by charter of King John, was the greatest fair in England, perhaps the greatest in Western Europe. Moreover as the Oxford school wisely kept clear of bishop and monk, so those who settled in Cambridge squatted just without the grip of Ely. Oxford, the courtly city, a centre of public affairs, became the picturesque stronghold of hierarchical traditions ; while Cambridge, happy in having no early history, was let alone to develop 'its Whiggism, and its mathematical school.' When, in the interests of Rome, James II brutally harried Oxford, Cambridge was, comparatively speaking, unhurt ; yet Oxford—engrained in its submission to authority in Church and State—was nevertheless still hotly Jacobite in the rising of Forty-five.

For like reasons Oxford sprang more suddenly than Cambridge into fame ; scarcely had European scholars begun to gather there at the opening of the thirteenth century when it grew rapidly into one of the largest schools in the world ; chiefly, as it would appear, on the scholastic side, under the influence of the Friars Minors. The Franciscans settled in Oxford in 1224, the Dominicans had preceded them in 1221. In these



Orders the professions of poverty and simplicity did not then extend to penury of the mind. Happily the great teachers Hales and Albert, each of whom in his own Order opened out a career for profane learning, were for their age rare scholars. Hales was a lesser light than Albert, yet Hales, under the encouragement of the learned and enlightened Gregory X, was reading and expounding the Arabian Aristotle: beyond the mutilated Organon known to the twelfth century, he had other treatises before him, physical and metaphysical; and the former were a potent aid in the revival of natural science. But Oxford held one greater both of heart and mind than either of these—Robert of Lincoln; who, and whose pupils Adam Marsh and Roger Bacon, became Greek scholars of no inconsiderable attainment at a time when Greek had virtually died out of the West. To a Studium Generale of the Middle Ages the potable gold of Greek tradition came slowly and hardly; trickling down in scanty and turbid rills, or choked at its sources. For a hundred years at least after the rage and wreck of the Dark Ages—of the sixth and<sup>1</sup> seventh centuries—had crushed it out of England and hither Europe, slender stores of Greek survived in the schools of Salerno (as the vehicle of Methodist Medicine), at Aurillac<sup>2</sup>, and in Ireland<sup>3</sup>. Alcuin of York died in 804,

<sup>1</sup> Even in Italy, owing partly to the distracted state of the Peninsula and in part to its Latin civilization, Greek was disappearing as early as the sixth century; and translations of Galen, Soranus, Rufus, Oribasius, &c., into more or less barbarous Latin were prescribed by Cassiodorus for his monks: these and such counterfeits held the field for some centuries, even in Salerno, and indeed carried forward some civilizing tradition.

<sup>2</sup> William of Auvergne was born at Aurillac, and there is some little evidence that he used books in Greek.

<sup>3</sup> Irish monks wandered about Europe, not a few of them; but whatever their personal influence may have been, they founded no schools.



and in the ninth century neither in Oxford nor in Cambridge, so far as we know, were there schools to attract the teaching of Erigena; we do not find indeed at the court of Charles the Bald, where he was withstood by Hincmar, the Hildebrand of Rheims, that any Greek or philosophical teaching of his took root. Erigena was but a meteor in the history of medieval culture, yet some sparks of his fire kindled the Moslem schools of Spain, whence Avicbron handed on the 'Scottish' torch to Duns. The study of Canon and even of Civil Law seems to have survived that of the arts and sciences, and in the tenth century the law school of Pavia had some reputation. In a few schools of Italy and Germany also, in the time of Otho the Great, the lamp of learning still burnt fitfully.

In the thirteenth century, when Oxford began, we have evidence that Greek was taught, and for a short time even flourished; but of its quantity or quality we have little evidence: in England, as elsewhere in Western Europe until the fifteenth, or rather early sixteenth, century, in spite of a renewed effort to establish it in the first quarter of the fourteenth century, Greek, as I have said, seems soon to have died out again, and with it the inspiration of natural knowledge.

In the eyes of monk and mass priest the friar, and above all the academic friar, was abominable; thus, fortunately, the makers of the University clustered about the parvises of St. Mary's—the Mont St. Gèneviève of Oxford—rather than within the cloisters of St. Frideswide or Oseney; the need of education for the secular clergy being perhaps a principal factor in the growth of these schools: such indeed was Merton's avowed purpose. Chroniclers rather than philosophers, no monk,



not even a Benedictine, entered the arena of scholastic disputation.

We need not take up the old question why Roger Bacon became a Minor? This question can only be solved by remembering that all teaching, and indeed all intellectual life, was then in the hands of the clergy; and that even the freemasonry of the informal tonsure conferred substantial immunities upon the errant scholar. Let us endeavour also to picture the enthusiasm of the time when the radiance of the evangelist who founded the Order, who had breathed a larger and humaner spirit into the world, as St. Augustine and St. Bernard had done, was still in its afterglow; of the time before the tide of the Faith against audacious and impious philosophers had turned in Paris and Oxford, as in the eleventh and twelfth centuries it had done in Baghdad; in the generation before the Victorians and Bonaventura became the Sufis of Europe. Whether in Orient or Occident, mysticism and scepticism are—to use the language of the physicist—the ions of the disintegration of creeds.

The Preaching Friars were always on the side of authority, indeed in 1243 the Dominicans came to the decision to abstain from the study of physical and medical science; the Minors on the other hand were then a vigorous and healthy force in support of the people against the usurpations of the nobles, of the Crown, and of Rome herself. Adam Marsh, himself a Minor, was a statesman, a close friend of Simon of Montfort, and moreover a champion of that freedom of learning which abates ecclesiastical and feudal pretensions. Balliol, where we are now gathered together, was founded under Franciscan influence. And was it not due to



this first temper of the new university, and perhaps of Balliol, that in the next century, and then in the teeth of the Greyfriars, Oxford was keenly Lollard? It is certain that with the suppression of Lollardism all intellectual life deserted her courts; and, producing nothing but tracts on alchemy and magic, she shrank to one-fifth of her former numbers.

Alexander of Hales, the leader of thought in Paris, was General of the Minors. Robert of Lincoln, who made Oxford—as Abélard made Paris, and Fulbert made Chartres—and who was the father Sarpi of the University in the early thirteenth century, was himself Rector of the Order, and bequeathed his library to it; and had Adam Marsh, on the death of Hales, accepted the office of General of the Order, the cause of learning and science might have withstood its adversaries; and the sowing of Bacon's genius might have had another harvest. Herein the desire of Grosseteste to keep Adam Marsh for Oxford was successful at the cost of Western civilization.

We are too apt to look back upon the thirteenth century with the eyes of Langland and Chaucer; or, through the lurid light of the sixteenth, with the eyes of Montaigne. In the thirteenth century men wrote respectfully of the friars; Roger Bacon, like Grosseteste, was not only a faithful son of the Church, but he was fired also by the conviction that in the study of nature he was treading one of the paths of divine revelation. This was the conviction which dictated the passionate pages of the epistles to Clement. The Franciscan was soon to travel as far from St. Francis as the Christian from Christ; but for the moment the barbarity which had wrecked the world, and the asceticism



which had spurned the filth of the flesh, were melting away in the sunshine of Saint Francis' sweet converse with all created things. As yet the Sorbonne was not, or was only in its kittenhood: the ironic prudence of Padua was not yet formulated. Albert at Cologne, vindicating against Paris the science of the Arab schools, dignified the study of natural knowledge and experiment; and this is his true title to fame. Glorious churches, new and splendid arts were springing up on all sides. Famous schools received new foundations, and privileges from popes and kings; Canon and Civil Law were opening out new careers; and the Church scarcely awake to its danger, forgetful of Erigena, Roscelin, Abélard, Amaury, and David of Dinan, was for the moment proud of its vocation to rule in the realm of faith with a docile philosophy, and science the servant of philosophy. Both in England and abroad the Friars Minors were for a moment the chief ministers of the new learning, as the monks had been of the old; and for a few short years they deserved this honour, in which season it was that Oxford, the offspring of Paris, under the inspiration of the great Franciscans who made its school, drew the breath of life, and prepared the way for Walter of Merton, the friend of Marsh, for William of Durham, John Balliol, and Hugh of Ely, who laid the stable foundations of the two great and ancient Universities of England; Universities which, during the adversity of Paris in the fourteenth century, were greatly strengthened and enlarged.

The encroachment of Civil upon Canon Law, which made some way at Bologna, had offended the Papacy; which was therefore disposed to favour Paris, and to inflate its theological and dialectical schools. In Oxford,



it is true, the Faculty of Civil Law grew stronger than in Paris, and derived some strength directly from Bologna; moreover in England the Common Law was stealing away the prerogatives of both; yet in order to understand early Oxford aright we must remember that Oxford was a child rather of Paris than of Italy, and, like Paris, harshly resisted the Italian culture.

The pioneers of science may be divided into two kinds: into a group of men who, like Galileo, Boyle, and Harvey, were themselves discoverers, and a second group, like Roger Bacon, Telesio, Campanella, Francis Bacon, Ramus, or Marsilio, who did service rather as protestants and reformers of method. Whether Roger Bacon were more of a chemist than Albert of Cologne, or either of them got beyond the chemistry of Geber; whether again in optics, his special study, Bacon advanced beyond Al Hazen, it is perhaps less important now to ascertain than to declare Bacon's glory to be that with a new and a passionate insight he proclaimed the true method of investigation.

But we must no longer say that Roger Bacon sprang up as a voice in the night, alone. That his voice rang with a clearness, depth, and certainty beyond the voices of all other prophets of his age is sure; to suppose that he cried as a solitary out of the darkness would be against the probabilities of history. Hales, it is true, was little more than an eminent schoolman, in outlook even behind Albert: but Grosseteste had larger visions than either; he was no inconsiderable geometer; he wrote a treatise *De Iride et de Cometis*, and was a keen inquirer into new sources of knowledge, including the 'Res Physica' or Medicine. Our records of the researches of the time are scanty; the rivalries of



priority, indeed the duties of acknowledgement, were practically unknown in Bacon's day, and for long afterwards; but Bacon was acquainted with the remarkable dynamical work of Nemorarius, and he generously proclaims his debt to Peter of Méricourt<sup>1</sup>—a Picard—of whose observations in magnetism we hear from no less a man than Gilbert<sup>2</sup>; this Peter moreover, so Bacon tells us, was a contemner of dialectical tangles and a master of experiment. Thomas Bungay, the eighth Provincial Minister of the Friars Minors, is well known by name as an associate of Bacon; he was probably engaged with Bacon in natural investigation, and, like other such inquirers, including Albert and even Sylvester the Second, was regarded as a wizard. Mr. Little tells us that Bungay lectured in Cambridge also, 'being the fifteenth in the list of Franciscan Masters there<sup>3</sup>.' To Bungay Mons. Charles attributes a manuscript in the Bodleian (E Musaeo 155, pp. 414-26) beginning 'Amicorum intime, quamdam magnetis lapidis,' &c. Mr. Little thinks that even Peckham came more or less under the influence of Bacon.

The rich outpouring of Arab science, quickly as it was mopped up again by the Church, inspired many of the more original minds of the age with a love of natural knowledge, and in Italy thenceforth natural science recovered some abundance of life; but in Paris on the Isis, as in Paris on the Seine, scholasticism surged up again, and these rudiments of natural knowledge were buried

<sup>1</sup> See Appendix.

<sup>2</sup> Mere allusions to the magnet as a compass are not uncommon even in the thirteenth century; as by Alexander Neckham, and Brunetto Latini, or earlier writers. The magnet was floated on a straw in water. There are many MSS., in Oxford and elsewhere, of Peter's letter on Magnetism.

<sup>3</sup> *Grey Friars in Oxford*, 1892, p. 153.



under the Aristotelian-Galenical cenotaph by that busy gravedigger Duns the Northumbrian; and were not dug up again till the day of Abbot Maurolycus and Vesalius, nearly three centuries later. Grosseteste and Adam Marsh had gone to their rest; Roger Bacon was prisoner of war; and not only was natural science extinguished, but a little later Greek letters also disappeared, until the time of Grocyn, Linacre, and Colet—in Mr. Rashdall's words, 'the most fascinating decade (1490-1500) of Oxford annals.' The world, it seems, was too young yet to quench its passion to begin at the core of things; its passion to carry the inner fortress of truth by assault, with the proud engines of the Faith:

' Hoping to still these obstinate questionings  
Of thee and thine, by forcing some lone ghost,  
Thy messenger, to render up the tale  
Of what we are.'

Was a fervour such as this to be spent upon secular collections of curious information; to be attenuated into multifarious plodding sagacities?

So it came about that one of the most genial societies, and one of the most piercing intellects our land has produced founded no school; though Dr. Bridges illustrates the persistence of energy by the interesting observation that Bacon's work on the error of the Julian Calendar influenced Paul of Middelburg, which Paul it was who urged Copernicus to make more accurate astronomical tables. Bacon noted also the error in the precession of the equinoxes, and compared the rainbow with the spectrum observed when on a summer's day the sun's light enters a chamber by a small opening. It is not easy, however, to claim for him much more than was known to the Arabian schools,



which he followed also in his belief in judicial astrology, a belief which William of Auvergne perhaps stood alone in denouncing. That Bacon's 'Perspectiva,' even if known to Descartes, had much influence upon his optical researches is, I think, a hazardous proposition. Had Descartes been in possession of the *Opus Maius* he might have got some good out of it. Indeed, the evidence seems to me to be against Dr. Bridges's attribution to Bacon of the discovery of the parabolic concave mirror, and its focus.

If I may rely upon the series of able essays on the history of science published a few years ago by Wiedermann<sup>1</sup>, and especially upon the essay of 1890 on the history of the burning glass, which he founds in part on two unpublished papers in the India Office, this mirror (obtained by conic section) and its focal properties had been described by Al Hazen. More, I think, was known to the Arabs and taught by them than is generally admitted. We know that Alfred Sershall was lecturing on Arab physics when Bacon was born; and it is to a very remarkable man, Nemorarius of Borgentreich, who died in 1236, and of whose researches Bacon was aware, that we owe the first departure from the statical conceptions of the Greeks and Arabs, and the initiation of dynamics. Dr. Bridges, however, attributes to Bacon the very interesting axiom that not sound only, as Aristotle knew, but all radiations of force also, in any of its modes, must take time, however incalculable the durations; this, in respect of light, Aristotle had denied. Indeed no Greek had conceived of measurable forces as causes of changes of motion; it was left for Galileo to begin the proof that they are calculable quantities.

<sup>1</sup> Wiedermann's *Ann.*, 1873, 1883, 1884, 1890.



Bacon stated also that substances opaque to light are penetrable by other radiations, as by those of heat or sound. But, it cannot be admitted that Bacon, or any immediate follower of Bacon, 'set the problem' of the telescope; if by this we are to understand the discovery of its principles without their technical realization. He and others before him had no doubt attached a convex to a concave lens, and ascertained that near objects become larger and nearer thereby; this, and moreover that spherical and even chromatic aberration are thus diminished, was known in early times; but the telescope seems to have been wholly unknown even to that consummate mechanic Tycho Brahe in the latter part of the sixteenth century.

By the name of Tycho we may be reminded that in the History of the Natural Sciences too little emphasis has been laid upon the construction of apparatus. Guilds of such artificers existed in England in and after the thirteenth century, and in Italy still earlier; but with one accord the great experimenters, even those of the sixteenth and seventeenth century, complained of the difficulty of obtaining craftsmen even skilled enough to carry out the designs submitted to them. Nevertheless valuable instruments were made somehow; and multiplied discovery prodigiously. The names of many ingenious constructors occur to us at once: of Archimedes, of Hero, of Leonardo, of Tycho Brahe, of Gilbert, of Galileo, of Huyghens, of Hooke, of Papin; as in our own times of Faraday, or of Ludwig: how various and elaborate indeed such apparatus had become even in the seventeenth century we may see in the Demonstration Books of Gravesande, the Dutch disciple of Newton, and of van Musschenbroek. In this field of research



Oxford is not inglorious; here Roger Bacon, whose expenditure of money and labour upon machines seems to have been enormous, was a forerunner of Boyle and Hooke. Nor are we to suppose that Roger's machines were clumsy and rudimentary; the Alexandrian and Byzantine Greeks, and after them the Arabs, had constructed apparatus of surprising elaboration and ingenuity; and we may be sure that Bacon's machines were well abreast of their time: unhappily, like the author of their being, they fell into decay and oblivion. The Dover Castle clock, with a horizontal pendulum or governor, taken down but in 1872 and removed to S. Kensington, was set up in 1348, and is still in going order.

We are apt to suppose that experiment is a new thing; it is no new thing: Aristotle made experiments, even Pliny made experiments; Bacon and Bungay made experiments, Albert of Cologne and Nicholas of Cusa made experiments; from those days to these experiments have never ceased; yet modern science is built not on experiments but on the experimental method. I have said already that herein, and not in any discovery which has come down to us from him, nor only in his refusal to grind up the ancients in a logical mill, lies the glorious memory of Roger Bacon. Before Galileo, he it was who first proclaimed, and proclaimed earnestly, that by the ordering of experiment after a definite plan discovery is to be guided, doctrine tested, error dissipated, and the succession of natural phenomena ascertained. Roger Bacon proclaimed, what even Aristotle did not comprehend, that casual experiments are but curious incidents; and that knowledge consists not in accumulation of curious incidents, nor indeed in divination of remote or



primary causes wherein effects are to be found, nor again in searching behind phenomena for their essences or formative substances, but in detecting by the *Experimental Method* the series in which they occur. A remarkable example of his insight we find in Bacon's conception not only of the scientific value of wide and accurate scholarship, which is attested by the silent witness of his works on Greek Grammar, one of which now lies in the library of Corpus Christi College, but also of the comparative study of languages; this latter conception was never attained even by the great humanists of the times of Erasmus and Casaubon, and indeed we are disposed to regard it as peculiarly our own. Finally Bacon discriminated between experiment and observation, even more clearly than certain newspaper correspondents of the twentieth century. If particular discoveries attributed to Bacon may be none of his, to declare that his work was but criticism, if great criticism, is then a grave historical error. His conceptions were as constructive of true method as they were destructive of false; and in the long run to construct a true method is a greater service to mankind than to discover items of knowledge.

Times of decadence have their heroes, as times of growth; and on Bacon's eclipse the able and conspicuous man of the decadence of Oxford was Duns Scotus, probably a Northumbrian: by Duns the waste products of thought were spun into a shoddy which for three centuries made the shroud of Oxford science. So late as the sixteenth century Tyndal speaks of 'the barkynge cures Dunce's disciples, and lyke draffe called Scotistes, the children of darkness—who raged in every pulpit against Greke, Latin and Hebrue.' In



the fourteenth century, such learning as the regular clergy had harboured in the neolatin period, since the day of Cassiodorus, was dissolving in worldliness; the poverty of the friar was becoming a sturdy and impudent trade, and the blight of the Black Death fell upon the folk; yet as in the long wars Paris waned, Oxford and Cambridge grew; and in Oxford—the Wittenberg of the fourteenth century—Wycliffe arose, kindled and edified by that father of the Reformers, Ockham; the Luther of the Middle Ages, as Bacon was the Galileo, and Chaucer the Montaigne<sup>1</sup>. In Wycliffe the Oxford man of science has his part: for before Luther he asked Luther's question 'Warum?'; and on Wycliffe also it was retorted that *cur, quare, and quomodo* were the words of infidels, and of the Devil himself who started *un pourquoi* in the Garden of Eden. Nay, to us Wycliffe seems even nearer than Luther, who was apt to look upon all science and philosophy as *Γνώσις ψευδώνυμος*. In the fourteenth century the strong discipline which had consolidated Europe was yielding in every direction; government was no longer a monopoly; at the Senior University of Europe—at Bologna—the Civil Law, as I have said, was permeating the Canon Law; the third estate was growing up; and, in 1378, even the very chair of Peter warped and split. Italy, then the intellectual head of Europe, was ablaze with the New Learning, and teeming with men who were mirrors and torches of culture; 'although,' as Thomas Wright of Oxford put it a little later, 'with brazen faces they be deprehended in enormous crimes<sup>2</sup>.' The great

<sup>1</sup> And Chaucer, like Montaigne and Rabelais, brought his vernacular tongue into the world of letters.

<sup>2</sup> *Passions of the Mind*, London, 1604.



maritime adventurers also were not only enlarging geography and widening men's conception of the earth, but they were forwarding also the study of astronomy, of the magnet, and thus onward of instruments of precision in other kinds.

Even in the evil sixteenth century the school of Cosenza, though soon stifled by the Jesuits, denounced the scholastic Aristotle; Regent Murray and George Buchanan established Ramism at St. Andrews, and Ascham brought it to Cambridge, while Melanchthon and his followers were restoring the true Aristotle. And even in Parisian Oxford, which repudiated More and Greek letters, the yoke of theology, which has dominated the natural sciences, almost to our own day, with a thralldom which Cambridge, always more Italian and less aristocratical, partially escaped; even in Oxford this yoke had been lightened by the gospel of Wycliffe. About 1480 Cornelius Vitelli had taught Greek in the University. William Selling also, and Linacre, the master of Erasmus, returning from the feet of Politian, brought to England the waters of this well of all the sciences<sup>1</sup>. Andrew Boorde, who visited and revisited the universities of the Continent, was perhaps the first writer on Sanitation after the passing of Salerno; and perhaps the first after Hippocrates to discuss the aspect and health of dwellings. Great was the wealth which the fifteenth century had poured into the lap of the sixteenth; but at this time the functions of Oxford as a seat of government were not altogether to its advantage as a seat of learning. Parliaments had been held in Oxford occa-

<sup>1</sup> Lily, the first High Master of St. Paul's, appointed by Colet in 1510, was unable to find a teacher of Greek in Venice.



sionally, from the thirteenth century, so that the hierarchical reaction of the sixteenth was severely felt in city and university. The example of enlightened tolerance which Leo X had set to Francis I and to Henry was soon to be quenched. Erasmus, more fortunate than Dolet, died just in time to save his skin: after Henry and Wolsey came Mary and Pole; after Leo and Bembo, Paul IV, Pius V, the preacher of persecution, Catherine of Medici, the black-hearted Guises, and the eve of Bartholomew; Oxford and Cambridge, however, suffered far less than Paris from civil and religious tyranny, and were not grievously despoiled.

A great historian has said that liberty never yet entered a country without bringing knowledge and taste, art and science in its train. Even of civil societies this doctrine would need much qualification, especially as regards despotism and 'taste'; the converse, however, is true; and Paris learnt the bitter lesson that when liberty was put to flight the spirit of truth flew with it.

Elizabeth, ploughing painfully with the Romanist ox and the Anglican ass, yet never forgot the countenance which her great house had given to learning; she was attracted by Italian culture, and showed some favour to the Universities; she went indeed so far as to order two bodies of her criminals to be delivered yearly to Cambridge for dissection; a boon we would willingly recover to-day. The countenance of Charles I to science it were ungrateful to forget; and even the renegade James II was more a termagant than a wolf in Oxford.

Near the end of the sixteenth century, when the fashion of Italian learning, language, and manners upon England still prevailed, and when all religious



fugitives were welcome, we get a curious glimpse of the Oxford of the day in the life of Bruno. Bruno visited England in June, 1583, with the French Ambassador, Castelnau, the translator of Ramus, and a man of learning, who protected Bruno as de Noailles protected Campanella. Bruno entered Oxford at the time of the enthusiastic reception of the notorious Lasco, a Polish noble and bishop of fabulous wealth, and a convert to Protestantism, who soon afterwards absconded, over head and ears in debt, ungratefully carrying off with him two alchemists, Dee and Kelly; who may have failed to prove themselves valuable booty. Bruno narrates that Leicester, then Chancellor of Oxford, with Dr. Humphred, Tobias Mathew, Arthur Gellard, Martin Colepepper, and Herbert Westphaling<sup>1</sup>, met Lasco, and conducted him in triumph to Carfax. Pageants, plays, banquets and oratorical exercises, at All Souls, Christ Church, Magdalen, and Woodstock, lasted for three days; while Lasco 'deliciis literariis satiari non poteret<sup>2</sup>.' Bruno gives an amusing account of the disputations; the titles of two of them being *Is it possible to predict by means of the stars?* and *Are men longer lived than women?* Poor science, no doubt; and Bruno

<sup>1</sup> The name of Herbert Westphaling raised some pleasant memory, which for a while I failed to recall till it came back to me in Walton's *Life of Hooker*. Westphaling was Vice-Chancellor when Hooker incepted in Arts in 1576.

<sup>2</sup> The blustering comedy of the great preparations for the christening of Jacob Barnet, the fury of the Heads on his elopement, the capture of this learned Jew on the London road, his incarceration and pains in Bocardo, Casaubon's mediation and the release and expulsion of Jacob, as told by Pattison in the *Life of Casaubon*, will come into the mind of the reader. But in speaking of Casaubon's visit as a singular glimpse into Oxford before Wood's time, the Rector may not have remembered Bruno's visit some thirty years previously.



was to try to teach Oxford better. The Earth, said Aristotle, Paris, and Oxford, is motionless; the Universe is finite, and moves. Bruno, in the name of Philolaus and Copernicus, protested that the Earth revolves; and that the Universe is infinite. The dispute grew venomous. Bruno declares that he stopped the mouths of the Doctors fifteen times; but we have heard of these fifteen refutations in other stories. 'Vide, tace,' says one of them pompously, 'et disce; ego te docebo Ptolemaeum et Copernicum'—as we say to-day, 'I'm not arguing with you, I'm just telling you'; but no sooner did he describe the heavens than Bruno quickly proved to him he had no acquaintance with the treatise of Copernicus! Another, says Bruno, drew himself up, placed his hands on the table, cast a glance around, lifted his eyes serenely to heaven, smiled subtly, turned his tongue in his mouth, spat on the floor, and began: 'Intelligis, Domine, quae diximus?' In the *Satyre Ménippée* it was not the orator but the audience which 'sonorement et théologiquement tousse, crache et recrache, pour ouyr plus attentivement.' Another Doctor shouted at Bruno, 'Quid! nonne Anticyras navigas? tu, ille philosophorum protoplastes, qui nec Ptolomaeo nec tot tantorumque philosophorum et astronomorum maiestati quippiam concedas'; and so forth.

Bruno, after these functions, in a letter written in the *humeur fanfaronne* characteristic of the time, and of these tribunes of free thought, asked permission to teach in Oxford; and it was granted him. We may regard his claim to be 'dormitantium animorum excubitor'—so Ulrich von Hutten called himself the 'Auferwecker'—as a reproach to Oxford, or a compliment to himself; but I fear Bruno's sallies were as ill received



in Oxford, which was still a 'fief of Aristotle,' as in Paris: he seems to have been even less successful in combating the physics of Aristotle than was Ramus in respect of his dialectics, and Luther of his ethics. Oxford said of him, 'He has actually written against Aristotle; and he is suspected of worse things still.' At this time in Oxford, as in Paris, Aristotle ruled by statute; and deviation from the Organon involved a fine. Bruno's lectures were on Cosmography, on Physics, on Psychology, and even on that grievous matter of the individual or universal soul, on which, so long as the Church could not get at them, the Paduan Averroists disgorged their rhetoric<sup>1</sup>. The English scholars seemed, I fear, rather blockish; or was it that Bruno was something of a bore? However, if he found the men clownish, ignorant, and deaf to the voice of science, happily the daughters of the Thames made amends for them.

'Belle e graziose ninfe, virtuose e leggiadre dame.'

Women are good listeners, especially to rhetoricians; but the lucky Bruno was adoring Rosalind, Imogen and Perdita; nay, Portia also was not made in Italy.

If Oxford reflected the manners of Paris, if its professors were courtiers, as on Anglican principles the bishops were princes, at Cambridge also, I regret to find—though the history of the sister Universities is by no means always parallel—that Sir John Price, Visitor

<sup>1</sup> How in the sixteenth century matters of knowledge were not tested but discussed, is well shown in Thomas Wright's *Clymactericall Yeares*, published in 1604. Wright, having taken an ague at Como, holds a 'Symposium,' in which the nature of an ague is discussed by two physicians, a doctor of divinity, and himself. Having threshed the matter out thus, they accepted that opinion which they 'liked best' as the true one.



of the Monasteries, at the time of the great Visitation in 1535, 'observed in the Heads great pertinacity to their old blindness'; but, he added, 'that if they were gradually removed, learning would flourish here; as the younger sort be of much towardness.' Even to-day I observe that the elders of dignified colleges are given to understand that the future is with their scholars, not with themselves.

Before we approach the brilliant band of Oxford men of science in the seventeenth century, we may return for a moment to the name of Robert Recorde, fellow of All Souls, and doctor of medicine of Cambridge in 1534. Recorde is an interesting example of the integrity of science and medicine; for in Oxford, among other things, he taught mathematics, rhetoric, cosmography, astrology, anatomy, and even music. He was a zealous antiquary also. Recorde seems to have introduced algebra into England; and his *Whetstone of Witte*, a book of advanced arithmetic, is said to be 'an oasis in an age deficient in science<sup>1</sup>.' He practised medicine under Edward VI, and, although a protestant and a reformer, in Mary's reign also. He is interesting to us now as one of the first advocates of the Copernican theory, which was propounded as an unproved hypothesis in 1543. We cannot wonder if in such dangerous times Recorde was something of a trimmer; as would appear from his writings, he made some terms with geocentric dignitaries; with an '*Astronomia caudataria*.'

In the year 1610, when Henry the Fourth had fallen under the dagger of Ravailac, the parliament of France

<sup>1</sup> *Dict. Nat. Biog.*



seized the occasion to ordain a suppression of the doctrines of Ramus; and, to reinforce the scholastic foundations of religious teaching, laid down elaborate schedules for the courses of philosophy in Paris<sup>1</sup>. But for Richelieu's favour, Gassendi's first volume of the *Exercitationes paradoxicae*, published in 1624, would have cost him dear; and he did not dare to continue the work. The Faculty of Theology expelled the opponents of medieval Aristotelian pedagogy from France, and burnt their theses. Even Descartes, who had dedicated his *Meditations* to the Sorbonne, and fawned upon the reactionary party to the point of declining to receive Galileo, whom Milton visited in prison; even he, one is almost thankful to say, found it convenient to reside in Holland, where, in his own words, he expired 'in the realm of the bears, between the rocks and the glaciers.'

History discovers to us that orthodoxy is a social rather than a religious need; and that if these needs come into conflict it is not society which goes to the wall. Happily, then, in the seventeenth century, 'certain extravagant chemists,' some of whom Oxford holds in proud memory, Ramists, Paracelsians, and Italianate philosophers, if many of them were short of religion, were shrewdly assisted by a new social factor; by the worlds of letters and of polite society. As Petrarch and Boccaccio scoffed at the academic coxcombs of Padua, so in France, two hundred years later, the sceptical *bonhomie* of Montaigne, the revolutionary philosophy of Charron, the merciless raillery of the *Mariage Forcé*, and the

<sup>1</sup> In Oxford fifty years later the chief condition for the degree of M.D. was three years' attendance upon lectures in Arabic.



polished satire of Boileau, did more to pierce the armour of the Church than the hardier rebels had done to bruise it. By them the shabby Aristotelian effigy, long battered by the weapons of Roger Bacon, Galileo, Harvey, Telesio, Descartes, and Locke, and bedaubed with the missiles of Patrizzi, of Ramus, of Verulam, was at last broken up and demolished.

*Absit omen*; but the growth of the natural sciences has never been a continuously ascending curve: like that of the fine arts, and in synchronism with it, it has flowed and ebbed, with long sandy wastes on the ebb. The century which begat Albert and Roger Bacon begat also Giotto and the Gothic architecture; 1564 saw the death of Vesalius, but, blessed among years, brought forth Shakspeare and Galileo, while Tintoret was painting in the Scuola di San Rocco, and Michael Angelo in the Sistine; fourteen years later Harvey was born; in Boyle's childhood Inigo Jones was finishing the Banqueting Hall; and the time of the foundation of the Royal Society saw also the foundation of landscape painting by Hobbema and Ruysdael. Thus again, the first half of the nineteenth century which knew Wordsworth and Turner, Dalton and Darwin, saw modern music soar into life as quickly and triumphantly as did the great churches of Amiens and Lincoln in the fourteenth. On the coming of age of science in the seventeenth century the nurture of Oxford and Cambridge had borne a large part. An organ and a witness of this adolescence was the establishment of those learned societies which, in their commencement, were rather experimental laboratories; such as the Cimento, the Lincei, the Academy of Sciences of Paris, and the Royal Society: and in the creation of this last Oxford took a well-



known and important part<sup>1</sup>. Furthermore, it was fitting that this part should have been played in the courts of Wadham, which, like Emmanuel, had lately been founded in the cause of liberty of thought, and in our own day again has been the seat of a new schism. The story has been told so often that I must not tell it again at length. Warden Wilkins seems to have been a man of many gifts; as a politician his influence with both factions was considerable; he was, as Wood puts it, 'a learned man and a lover of such'; moreover he was comely of person and courtly of breeding. Evelyn, in his Diary, has left us an attractive picture of this 'most obliging and universally curious scholar,' his 'dear and excellent friend.'

At Wadham Wilkins gathered about him, in 1649, such men as Seth Ward the Savilian Professor of Astronomy, the incomparable Wren, Boyle, Wallis the Savilian Professor of Mathematics, Dr. Thomas Willis an eminent physician who introduced iatro-chemistry into England, Richard Lower the furtherer of Harvey's work, Goddard Warden of Merton and Fellow of the College of Physicians, Dean Bathurst, Sir William Petty, and others, who not only busied themselves in experiment, but also knew that only by methodical experiment is natural science to be built up<sup>2</sup>. Unfortunately no laboratory notes of that time are preserved, if indeed they were made; and of many series of interesting experiments we hear but by chance allusions.

The Royal Society did not draw its origin from Wad-

<sup>1</sup> Della Porta's *Accademia Secretorum Naturae* was the first of these; but, unlucky in its name, it fell under the suspicion of Paul III, who suppressed it.

<sup>2</sup> Hooke seems to have been brought into the circle by Boyle a few years later.



ham primarily; the scientific club had been wont to meet at the Gresham College from 1645: but the unsettled state of the realm made them desire less distracting quarters, where indeed the club was unpopular enough, but where skits and counterskits were the most poignant weapons of war. Nevertheless, of Wilkins it may be said, if of any one, that he was the founder of the Royal Society; he was chairman of the promoters during the initial stage, and he was the first secretary. Moreover, Mr. Wells is justified in making, on behalf of Wadham, the claim that his College was the cradle of that great society, for which the Royal Charter was obtained in 1662.

In recording the appointment of Wilkins to be Master of Trinity in 1659, I am reminded of the continual give and take between the Universities in those days. In reading the lives of the worthies of the time it is surprising how frequently translations take place; not only that teachers passed readily from one University to the other, as did Seth Ward or Wilkins, and as Recorde had done; but other graduates also, considerable and inconsiderable. We find graduates in Arts of the one taking the degree of M.D. in the other; a graduate of Laws in the one passing to a higher degree in the other; a Fellow of All Souls is M.A. of Cambridge, and so on: surely a most wholesome mutual indebtedness. Thus it is that to their common misfortune by railways places are divided.

Many years ago, from the sixpenny tray of a book-stall, I bought three sheepskin quartos of the works of Boyle; and made never a happier purchase. My admiration for a great man and, may I venture to add, my attachment to a new friend, began as I looked



between the leaves on my way from the bookseller to my lodging. In the history of ideas they are interesting books, in the revelation of a delightful character they are fascinating. What a perfect instrument was his mind; what a gentleman he was by nature and by breeding! In his essays Boyle reveals himself almost as Elia did; one learns to know him as one knows Montaigne. If at times he be a little garrulous, he is the more homely, the more intimate; but how quick, and how fresh is the irony of his 'Examen' of the rough onslaught of Thomas Hobbes upon the Gresham Society and upon Wallis, Ward, and himself; how polished and elegant his weapon when compared with the coarse violence of contemporary scholars and publicists. In one of those imaginary Dialogues, in which a man of straw is put up but to be beaten off by the prowess of the author, Hobbes had said, 'You confess then that your Collegiætes have as yet in nothing advanced the knowledge of natural causes; but that one of them has found out an engine in which there may be such a motion of the air excited that the parts of the sphere may together every way tend to the centre, and that the Hypotheses Hobbianæ, before probable enough, may be thence made more probable.' To this Boyle quietly says, 'If by this engine his hypotheses are made more probable, some will perchance think that to be enough to entitle my experiments to some degree of usefulness, unless Mr. Hobbs's doctrine of the air had found more embracers than, before these seasonable though despised experiments, it was observed to have.' How dignified the 'Examen' in its courtesy, how accomplished and how effective, may be read in this tract, printed at Oxford in 1662.



When, on his declining metaphysical conceptions, Hobbes taunts Boyle with making 'unobvious' (i. e. whimsical) experiments, Boyle upbraids Hobbes for endeavouring to disparage experiments, and to discourage others from making them; 'which if he could by his Dialogue effect, I dare be bold to say he would far more prejudice Philosophy by this one Tract than he can promote it by all his other writings. Wherefore though his disparaging of Experiments would probably have much more Authority if he had been the Author of considerable ones, yet, lest for all this his Fame and Confident way of writing might prejudice Experimental Philosophy in the minds of those who are yet strangers to it, I thought it not amiss' [to publish this vindication]. 'Tis easy for a great Wit frequently enough to mistake, and much more frequently to miss of clearly demonstrating what he pretends in matters Physical, for want of having sufficiently considered the experiments he would be thought to despise; and Mr. Hobbes' Adversaries need not be much ashamed of the name he has given them of "Experimentarian Philosophers."'

In the matter of his own investigations into the elasticity of the air—or the 'spring' of the air as he terms it—wherein Hobbes censures him that he 'has not gone into the cause of Springs in general,' that omission seeming to him very unworthy of a philosopher, Boyle points out that the Gresham College Society has forborne, for weighty reasons, 'to determine the causes of things, or to deduce them from Catholic principles of philosophy, but to devise and repeat experiments which may put opinions to trial and judgement.'

It would appear that Boyle began his work in science



at an early age; he says he 'first began to consider what Fluidity might be when quite a boy.' It is not only remarkable that he should have devoted himself to pursuits then far from common among the men of his time and circumstances, but also that he should have been endowed by nature with a temper so sensitive to truth, and with a sagacity and an industry in research, such as are not familiar even among men trained in the methods and equipped with the knowledge of our own generation. Both in practice and in his understanding Boyle seems to have grasped more clearly than did Bacon—whose works, by the way, he tells us he had hardly looked into lest they should prepossess him—the conception that science is advanced not by experiments but by the experimental method; and, far more clearly than Bacon, the place of hypothesis in research. In respect no doubt of the Summists of the Medieval Schools, of whom Robert Pullen, of Oxford, was the first and Francis Bacon not altogether beyond the limits of the last, Boyle says well, 'It has long seemed to me none of the least impediments of the real advancement of true natural philosophy that men have been so forward to write Systems of it, and have thought themselves obliged either to be altogether silent or not to write less than an entire body of Physiology.' This practice 'leads the student to suppose that the whole subject is already sufficiently explicated, and it were needless for them to put themselves to trouble and charges in making further inquiries, but thankfully to acquiesce. Subtle and inquisitive men who spend time in accurate Prosecution of research, and are thoroughly acquainted with the difficulty of clinical investigations, are least of all forward to write Systems.'



Boyle seems accordingly to have set the example of the scientific essay, of the 'paper' as we call it nowadays, whereby an author may convey to his public any new facts he may have discovered, and new opinions which he has formed, without supposing it needful for this partial advantage to write a capacious and systematic work in which indeed his own haporth of bread may chance to be lost. Furthermore, he tells us how to write our papers. In writing them he says 'the experiments should be described with the conclusions, or we may be in danger of erring with the writer; but if he describe his experiments, be his opinions never so false, we are at liberty to benefit by the former. And scientific writing should be rather clear and significant than curiously adorned'; on the other hand, while objecting to 'too spruce a style,' he adds, 'I approve not that dull and insipid way of writing which is practised by many chemists.'

Nor are we to confine ourselves to positive results, negative results are valuable; nay, we shall record our failures, for in nice experiments we have to learn how various and subtle are the conditions on which results depend. He urges also that for the inquirer no facts are too humble.

'I shall not scruple,' he writes, 'to confess to you that I disdain not to take Notice even of Ludicrous Experiments, and think that the "Plays of Boys" may sometimes deserve to be the Study of Philosophers . . . for Nature acts very seriously, and is in very good earnest, whether we Men be so or no . . . Learn hence this Lesson, That there are many Things in Nature that we disdainfully overlook as obvious or despicable, each of which would exercise our Understandings, if not pose



them too, if we would but attentively enough consider it, and not superficially contemplate, but attempt satisfactorily to explicate the nature of it.'

The playful banter with which Boyle disposes of cosmic philosophers, such as 'that most ingenious gentleman Monsieur Descartes,' is more effective than heavier artillery—'Those Heroic Wits to whom the Commonwealth of Learning is exceedingly beholden for plausible speculations in the most primitive and Catholick Affections of Matter.' He goes on to say that he is apt to impute 'many of the deficiencies to be met with in the theories and reasoning of such great wits as Aristotle or Campanella to this very thing, that they have too hastily and without a competent number of experiments presumed to establish principles and to deliver axioms.' And of this he gives a pretty illustration; that at Leyden he was admitted to a camera obscura which gave a lively representation of certain objects while they were looked on with a weak and indeterminate degree of light; so diverse philosophical theories may appear well proportioned fabrics, yet if the fuller light of new experiments and observations be freely let in upon them 'the Beauty of those delightful but Phantastical structures does immediately vanish. . . . To destroy them 'twere needless to bring battery engines, since nothing is requisite to this effect but a little increase of light.'

He perceives that the way to get reputation 'is to venture to explicate things and to promote opinions,' and is well aware that 'among the more daring and less considerate sort of men he will pass for a drudge of greater industry than reason, who may collect experiments for others.' But he himself had often found that



after 'framing notions and hypotheses' they were 'soon after disgraced by some farther or new experiment.'

On the other hand, he is quite clear as to the value of hypotheses, although he 'cannot but represent that a hypothesis depends not upon first principles,' but upon whether it stand the test of experiment or not. In contemplative moments he was wont to make lists of experiments whereby to test his ideas. He knows that 'a suspension of the exercise of reason is impossible,' and that it is conducive to the discovery of truth to permit the understanding to make hypotheses, 'and by its own errors to be instructed; yet such superstructures should be regarded as temporary, and to be tested with a proportionate number of experiments.' Whewell announces to us, in that judicial tone which oftentimes conceals injustice, that Boyle, although a meritorious and curious fact-digger, lacked the insight into methods and relations which is characteristic of genius. The Master of Trinity was rarely so much mistaken. Besides the laws on the volume and elasticity of gases, the chief of which work was done fifteen years before Mariotte, besides his researches on respiration, which led directly to Mayow and Cavendish, besides his more accurate quantitative estimations which prepared the way for Black, the careful reader of his works will, I think, admit that by his insight into chemical affinity, by the breadth, orderliness and exactness of his methods, and by his scorn of the theosophic mysticisms of Böhme and Fludd, he made chemistry for the first time an academic study.

His mind was very active concerning Solidity—'Firmness,' as he calls it—and Fluidity, and was unconvinced by the ascription of solidity by chemists to the



principle of 'form,' to a cementing spirit, or to a saline principle of coagulation; all of which explications do but throw the difficulty one step backward: or indeed offer an explanation harder than the problem itself; whereas, he often tells us, 'to explain a thing is to deduce it from something or other in Nature more known than itself.' For his own part he observes that the brief duration of the melted state does not remove such 'liquors' from the category of fluids for the time being. He feels sure that firmness and fluidity are concerned with some mutual attraction and dispersion of the minute particles of which bodies consist; and surmises that under certain conditions of intimate approximation they may hook on to each other. On this problem, as well as on those of the pressure of the air, he brought to bear the experiments on the adhesion of polished surfaces on which he was very often engaged. Why some fluids damp what they touch, and other fluids, such as quicksilver, do not, puzzles him for a time; but he discovers humidity to be a matter of congruence of the particles of the liquor with those of the body it touches. We are wont to attribute to Francis Bacon the conception that heat consists in a vehement motion of the invisible particles of bodies, but to Boyle this conception is a familiar one. For instance he said in 1659, 'Heat consists chiefly if not solely in vehement and tumultuous agitation of the small parts of Bodies,' on another page it is a 'nimble motion of their minute particles' (*New Exp. Phys.-Mech.*, 2nd ed., p. 204, and *Phys. Essays*, p. 137).

Of the value of authority he says, 'What this or that man thought I dispute not . . . there are degrees of reliance on others, however great their names.' Even



in quoting Aristotle, Theophrastus, or Pliny, for whom he had a sufficient respect, he remembers how hard he himself had found it to make and relate an observation faithfully; and thus, when he had looked into divers matters of facts delivered in their writings 'with a bold and impartial Curiosity,' he was shy of building upon foundations he esteemed so insecure; and much less would he rely upon the 'suspected Passages that Wecker, Paracelsus, Porta, &c., abound with.'

A very curious confession follows this paragraph, which may be perhaps attributed to Rosicrucian influences; namely, that he 'deliberately conceals some parts of his labours'; he has some 'experiments concealed'; he is 'always provided with some Rarity to barter with those Secretists that will not part with one Secret but in exchange for another; and think nothing worth their desiring that is known already to above one or two Persons.'

We must not suppose that Boyle made but showy, occasional, or argumentative experiments; his experimental researches were evidently very extensive and systematic; he is always ready to cite long series of them. Moreover in two essays on 'The Unsuccessfulness of Experiments' he betrays an astonishing personal experience of fallacies, and of their many causes; such as impurities, whether adulterations of materials of research, saying with van Helmont, 'quod venale extat, fraude plenum est,' or due to the variableness of natural bodies, such as ores, or herbs grown in diverse soils or seasons; or again the variable texture of specimens, such as of blocks of ice used in optical research; or latent errors in processes, even by persons 'assiduously conversant with the materials they em-



ploy'; or the variability of conditions, such as external temperatures and the like, sources of embarrassment which he illustrates by the perplexity of Aselli who failed on occasion to demonstrate the lacteals, but whose sagacity led him to detect the cause of failure in the time relation of feeding the animals. He also lays down rules of mean error of measurements, whether in the observer or in his apparatus, and appeals to 'indulgence for manifestly careful and modest observers'; nevertheless he would lay some claim to have used 'exacter scales and a somewhat more wary method than others seem to have done,' and to have prosecuted his inquiries in such several ways as should by their small differences assure him he was not much mistaken.

The range of his curiosity was boundless. A chance acquaintance told him how rarely he drank, sometimes not for days; Boyle promptly noted his complexion, and measured the amount and kinds of his diet, and the quantity of his urine. He tried to discover how substances, ordinarily insoluble, such as bones, could be 'dissociated' in a dog's stomach. In his travels he discusses technical processes with miners, with metal founders, with chemical manufacturers, with stone carvers; and draws the attention of such persons to interesting details previously unnoted by them.

Boyle began the study of nature as a chemist, and throughout his career chemistry was his chief occupation; but, soon perceiving the interdependence of the several spheres of natural knowledge, he says that his chemical researches led him to the physical 'because air is a necessary condition of living creatures, and also is concerned in many phenomena in which its part may be unsuspected.' He notices the spiracular respiration of



insects, such as bees; and discovers that 'the presence of the Air is more necessary to these animals than the presence of their own Heads' (*New Expts.*, p. 198). From a passing remark in the essays on the fallacies of observation we learn how assiduously he had attended upon dissections of the human body, and this by the way at a time when the nerves of the Regius Professor of Medicine of Oxford—Sir James Clayton, M.P. for the University—were too refined to allow him to assist at such nauseous exhibitions. As instances in this subject of such fallacies he mentions some of the now well-known variations of anatomical structure in man, with which he associates adhesion of the pleura, the degrees of which 'in his own experience,' he says, are very variable. Against 'the common opinion' that it is 'the motion of the thorax which fills (the lungs) with air' he alleges, 'As our learned friend Dr. Highmore hath well (and congruously to what ourselves have purposely tryed) observed, if a live Dog have a great wound made in his Chest, the Lobes of the Lungs on that side of the Mediastinum will subside and lie still . . . the diligent Bartholinus affirms the like of the Diaphragme also . . . indeed the Diaphragme seems the principal instrument of ordinary and gentle respiration, altho' to restrain respiration the intercostall Muscles, and perhaps some others, may be allowed eminently to concur.' In another place he shows how anatomical preparations can be preserved in certain liquors, and he took deep interest in Lower's remarkable experiments on the transfusion of blood, experiments suggested by Wren.

That 'positive levity, as some Peripateticks speak' is an imaginary quality Boyle had proved by observing the movement of vapours upwards as the upper strata of



the air grew thinner (i. e., as he explains elsewhere, as they have a lower column of superincumbent air on the given area) and are moved by currents. Also by the use of certain 'smoaks' in a still air, or in his receiver, he showed that such vapours found their levels just as do fountains or rills of water; furthermore, that even interfering flames may 'preserve their own surfaces.'

'Suction' he had proved to be 'pulsion not attraction'; and, in opposition to any supposed 'aversion of Nature to a Vacuum,' he demonstrated that air may be weighed in pounds and ounces, and its rise in exhausted tubes measured by inches. Add but an inch he says 'and you will surmount (Nature's) much magnified detestation of Vacuities.' Thus he arrives at the truth that the outer air rushes into the lungs because the pressure of the air within them is much weakened by the expansion of the chest; 'the lungs being dilated by being filled.'

It is remarkable how patiently he considers what now appear to us to be whimsical opinions and conjectures; disproving them by experiment after experiment, and acute argument. Some specious conjectures he had himself almost accepted, till he tried, observed acutely, and saw their falsity. Let us take for example the prevalent belief that the use of respiration was to cool the blood, an 'opinion which not only seems to be received amongst Scholastic Writers,' but also 'divers of the new Philosophers, Cartesians and others admit it with some variation.' This opinion he considers sagaciously; he does not see how it can apply to those animals which, respiring by lungs, live in cold water; or to cold-blooded animals which respire by lungs; or again to decrepit old men whose natural heat is very languid; or to persons languishing in disease but who often have the necessity



of frequent respiration. Moreover a temperate air is often better than a cold air. He suggests that it is against the economy of nature to make the blood of so excessive a heat that it needs to be perpetually cooled. Again, to his touch the heat of the heart of an animal does not feel burning, but gentle. He tests the ambient air about an animal dying in a sealed vessel, and finds it is not sensibly hotter than the common air. In his own dissections he could never see how the air is conveyed into the left ventricle of the heart; furthermore he notes that the systole and diastole of the lungs are not synchronical with those of the heart.

Boyle then turns to the hypothesis of the purification of the blood in the lungs from 'excrementitious steams.' The heart must need an 'ambient yielding body into which recrements of the blood may be expelled,' and in which ambient medium they may be conveyed out of the body by way of the 'aspera arteria.' Yet he thinks when the air is attenuated in the receiver of his pump the vapours should escape but the more readily, and the animal find a benefit in it. He rightly surmises that if a man should be carried aloft into the higher strata of the atmosphere he would die, as the mice do in his receiver; here unfortunately he is bewildered by the contradictory reports of travellers, but he quotes Josephus Acosta who was distressed on the higher mountains of Peru, and relieved again on his return to lower air. For he had proved that the atmosphere is not light but heavy, and its particles 'only not dissipated into space because their gravity hinders them.' His observations on gills lead him to perceive that they are analogous to lungs, and that air is necessary to fishes; and he proposes to experiment on the duration



of life in fishes in closed tanks of water, reminding us he had also proved that 'particles of interspersed air are apt to lurk in water, whereof it seems not impossible that Fishes may make some use, either by separating it, when they strain the water thorow their Gills, or by some other way.' Unfortunately the only living fish he could obtain at this time for his receiver was an eel, whose tenacity of life left him in a divided mind between the need of air to fishes and the unusually vivacious nature of eels. How gills should be a means of aërial respiration was no difficulty to Boyle, who, as I have said, by many experiments—such as the slight compressibility of tap water, and its behaviour under the air pump—had satisfied himself that under ordinary circumstances water contains air. By this mixture he suggested an explanation of the fact, which he attributes to 'our English Democritus, Dr. Harvey,' that the blood of the fetus is renewed in utero: 'in the womb,' he says, 'the fluids of the mother may hold air,' for 'even in the closest and most ponderous liquors there lurk undiscernable parcels of air which bubble out at low pressures.'

Nevertheless he still thinks it probable that there is something more in respiration than ventilation and depuration of blood. 'Methinks,' he says, 'it may be suspected that the air doth something more than barely help to carry off what is thrown out of the blood in its passage through the lungs. Surely a brief delay of these matters would not kill so quickly, for in disease they must be longer detained. . . . We may suppose there is in the air a little vital quintessence (if I may so call it) which serves to the refreshment and restauration of our vital spirits.' Barely to assert this, however, he adds, is idle until it be explicated and proved.



In this respect he refers with interest to the story of Drebbel's ship—a ship which, whether phantom or not, was a subject of much curiosity to the savants of the time—for it was alleged that in it men had voyaged under the surface of the Thames; an achievement for which, however, there seems to be no sure evidence. The story is discussed in the letters from Huyghens to Papin, edited by Gerland at Berlin in 1881, and by others; if I remember right by Pepys. Boyle suggests that Drebbel may have provided himself and his fellows in the ship with some 'spirituous part derived from the carcase of the air,' a conception which brings us very near Mayow. He concludes the discussion by saying, with St. Austin, 'Mallem quidem eorum quae a me quaesivisti habere scientiam quam ignorantiam; sed quia id nondum potui, magis eligo cautam ignorantiam confiteri quam falsam scientiam profiteri.'

It is needless for me to enter into the course of Boyle's researches upon the elasticity of the air, and on the phenomena of the air pump, for by these researches his name is immortalized. His means of measurement of air pressure by columns of mercury and of water are also the well-known parents of later manometers. In these researches he was embarrassed by the daily variations of the mercurial column—that is, at a given level, for of course he knew all about Pascal's observations on the Puy de Dome; he attributed them 'to some accidental mutations of the air'; he proved them not to be due to the temperature of the room, to changes of position, nor even to the tides of the sea, a notion which Wren, on the basis of Descartes' calculations, had suggested to him.

Boyle denied that he was either a Vacuist or a Plenist,



or an adherent of any such metaphysical doctrine favoured by Mr. Hobbes and others. While he proves that sound diminishes as the air is pumped out of the receiver he yet asserts that the vessel cannot be void, as objects if not audible are visible: this, he says, must signify either the emanation or the brisk motions of some subtle matter; for without some substance as its vehicle, he argues, 'it is not to be seriously imagined that light could be conveyed.' By farther experiments he proved that 'the magnetical steams of the earth always pervade' the exhausted receiver. We are apt perhaps to undervalue such reasoning because of the oddity, to us, of the technical terms used; but we shall remember that scientific nomenclature was then in an early stage of making, and that many words to which we are now accustomed are no better, some of them indeed worse, than those in use two hundred and fifty years ago.

Boyle, like many naturalists of the day, was much let by the want of artificers able and ingenious enough to construct machines; to this subject I have referred on a previous page (p. 16).

By dwelling upon Boyle I have left myself but little time to speak of his great Oxford contemporaries; of Wren, Hooke, Mayow, or Locke<sup>1</sup>. In Wren the architect we are apt to forget Wren the savant; indeed in the history of the natural sciences his rich and illustrious genius is rather fascinating than effectual. Yet, had he made natural science his field, Newton only of his fellows could have surpassed him. Boyle admired Wren as a student of physics and of physiology, who had

<sup>1</sup> Ståhl, a German chemist brought for a while to Oxford as a co-operator by Boyle, valuable as his services probably were, is scarcely to be counted as in any sense an Oxford man.



invented transfusion ; to him Newton owed some debt of mathematics ; even Hooke respected him as a rare mechanician. A chance comparison in Boyle of some philosophical rubbish to the 'ruins of Paul's,' is a vivid touch of the time ; and an unconscious signal of his friend's monumental fame.

Hooke abode on the field of natural science, and thereby achieved a work in which his dwarfish and fretful nature is transfigured in our eyes. If his name does not stand in the first rank, it may be that he had more insight than pertinacity. He had glimpses of many great truths—of the undulatory theory of light ; of the law of the inverse squares ; of the analysis of musical vibrations. He was the first to state clearly that the study of the heavens is a mechanical problem<sup>1</sup>. Hooke was closely associated with Boyle, both in his physical and physiological researches. As a mechanician he translated the ideas of his time into practice with rare ingenuity. Otto Guericke was no doubt the first to make the air pump ; but Hooke and Boyle, or Hooke for Boyle, made a better one, without seeing the model ; as Galileo made his telescope on the hearsay of one made in Holland. Hooke invented also the balance of the watch, though Huyghens was the first to put it into practice. Hooke and Grew, like Malpighi and Leeuwenhoek, worked with the microscope, but chiefly with the simple microscope ; the compound microscope at that day and for a century afterwards, on account of spherical and chromatic aberration, was almost useless. I am glad that Hooke is not—so far as I know—looking over

<sup>1</sup> The conception of the heavens which still ruled even great thinkers, like Harvey, I have set forth briefly in my little book, *Science and Medieval Thought* (pp. 47 and seq.).



my shoulder, for I would add in conclusion that he seems also to have been one of the discoverers of the jealous assertion of scientific priority.

On Mayow I may touch with disproportionate brevity ; for Sir Michael Foster has lately appreciated his work, in his *History of Physiology*. It had long been known that on venesection the dark blood turns red in the open air. Lower, Bathurst, Hooke, and Mayow proved that artificial respiration would reanimate the heart, and redden the blood. Boyle had shown that neither combustion nor respiration could continue in a closed chamber ; and Boyle, as I have said already, surmised that the air contains something quintessential to this end, which might be separable, as perhaps in Drebbel's ship, from the 'carcase of the air.' Mayow demonstrated that this part is even more richly contained in saltpetre and is virtually what we now call oxygen ('fire-air,' 'aërial spirit,' or 'nitre air'); moreover he proved that the increase of weight obtained by burning a metal such as quicksilver in air is to be attributed to its combination with this element<sup>1</sup>. Unhappily, as beforetime the cobwebs of Duns, so the phlogiston of Ståhl stopped all progress, until the birth of Lavoisier. Sir Michael Foster is disposed to put Boyle's contributions later than those of Mayow ; but Mayow's earliest tracts were published in 1668, Boyle's, from which I have quoted, in 1661. These bright spirits wrought together, apparently without envy ; and to try to apportion to each his share in the common growth, to deal to individual genius its part of the product of social genius, is, even in our own time, too curious an enterprise.

<sup>1</sup> The fact that metals increase in weight on calcination was well known before Mayow ; at any rate it was known to Boyle, and Ray had observed it in 1650.



Of the greatest names of the Oxford group one remains, one on whom I cannot be silent; Locke, the loyal friend of Boyle and of Newton, who did for the mind that which Harvey did for the body. Psychology, and this was one service of animistic speculations, had all through the Middle Ages lain within the scientific domain. The learned President of Corpus reminds us (Ed. *Nov. Org.* p. 271) that the 'affectus et prehensiones intellectuales' were among the objects of natural philosophy in ancient usage; the word psychology being a neologism. Thus the *De Anima* was always ranked among the physical works of Aristotle. In the old statutes of the University of Oxford, among the works on which the Praelector Naturalis Philosophiae was to lecture, were the *libri de anima*. Here I may refer also to the seventh book of the Ethics. To enter upon any adequate appreciation of Locke, were there need for a new appreciation, and were I apt for the task, would at this hour be impossible. I will content myself and you by saying, again in the words of the President of Corpus:—'There was never a thinker more wise, more methodical, more logical than Locke. Other reasoners had written a romance of the soul; Locke came and modestly wrote its history, developing the ideas of the human understanding as an accomplished anatomist explains the force of the human body' (Locke, 1881, p. 197). It would appear that Locke, on his strongest side, was scarcely understood by his great contemporaries; Wood gives us no more than a few trivial impressions of him, characteristic as these are.

When across the centuries we admire the constellations of great 'Wits'—to use their own word—of seventeenth-century Oxford, we are apt in our admira-



tion to think that the great mother was glad in them: and so in her own heart she may have been; but with the rest of her brood it was far otherwise. We see the Dean of Christ Church setting his poisoned traps for Locke, and tendering his servile offices to expel him. At the head of a gang of fops we see to our sorrow Hobbes, who had 'contracted a morosity,' pursuing the Scientific Society and its members with rancorous and pedantic censures. Thomas Sprat had to argue that experiments are not dangerous to Universities. Not only did pert young priests ask sarcastically to what purpose it is to preach to people, and go about to save them without a telescope and a glass for fleas! but even South also, the Public Orator, fulminated against the Royal Society at the opening of the Sheldonian. Of the Wadham College Library Mr. Wells says that such a collection enables us to realize the main interests of a seventeenth-century scholar. 'Every variety of theology, historical, doctrinal, above all controversial, is represented fully. . . . Long-forgotten Jesuits from Spain or Poland stand in dusty oblivion side by side with their opponents. Hales and Aquinas are as eminent as Erasmus and Luther. Scholars from all parts of Europe met, armed with the common language, Latin, on the common battlefield, Theology.'

For this monstrous trifling, this solemn pyramid building, in the desert, over the ashes of ghosts, a sore night was at hand. In 1642 the King entered Oxford, the toga yielded to arms; the babble of the school was lost in the din of the fortress, and for four years science and letters held their breath in the crisis of the nation. Happily among the captains of both factions were men who had been suckled at the breast of the



great mother, now again in travail, as the storm divided this way and that; they protected her life, but her heart was torn in their strife:—

*οὐκ οὖν ὄρμαιμος χῶ καταγτόν θανών; ὄρμαιμος ἐκ μιᾶς.*

In the beginning of the eighteenth century in England Berkeley was writing the *New Theory of Vision*, and Dick Steele was founding *The Tatler*; in France Clement XI was tearing down the walls of Port Royal and scattering the bones of the Jansenists. Fifty years later still, the implacable Sorbonne, by damning the treatise *De l'Esprit*, and the indefatigable Bishop of Rome, by burning it at the hands of the common hangman, bestowed on Helvetius the uneasy crown he merited so little. Truly our precious things are often in the keeping of most pernicious persons!

Meanwhile Oxford of the eighteenth century seems to the philosopher to have drifted almost farther away from us than the fourth century before Christ. In the eighteenth century the University was subsisting only upon the heritage of her great past; von Uffenbach, in 1710, reports that Boyle's 'elaboratory' was become the prey of rust and the worm; Mr. Wells says<sup>1</sup> that, even in 1794, an attempt to form what I will call the 'Junior Scientific Club' was promptly squelched by the Vice-Chancellor, and that its would-be members were dubbed 'The Lunatics': so Oxford slumbered on, to be awakened, not by the hum of the laboratory, but, as by Wycliffe three hundred years before, now anew by the thunders of Wesley, and the lightning of Newman, in St. Mary's; St. Mary's the nurse of her infancy, the venerable mother of her prime. St. Mary's and modern

<sup>1</sup> *History of Wadham College.*



physical science teach alike that between the material and the spiritual worlds there is no gulf; that in the death of either the other is also dead; and that in the life of each is their consummation. The Oxford sciences of our own day are happily too great a matter to make an end of my discourse; they are great enough to prove that—

‘Nature, crescent, does not grow alone  
In thews and bulk; but, as this temple waxes,  
The inward service of the mind and soul  
Grows wide withal.’



## APPENDIX

### PETER PEREGRINUS

(vide p. 13)

A GLANCE into origins reveals, among other things, the complacency with which even serious authors copy from each other. Names, phrases, paragraphs, nay, whole pages, are thus transferred word for word from old to new; the first maker of the stuff might complain, the several retailers cannot. Thus one historian after another talks familiarly of Peter Adziger as a forerunner of Roger Bacon, as familiarly as if Peter Adziger were as well known as Hales or Grosseteste. In another place we read of Peter of Maricourt, or of Maharne-court; in another of Petrus Peregrinus. In the Library of Cambridge University, with the help of my friend Mr. Francis, I satisfied myself that if these three Peters be alembicked into one Peter little will be lost on the distillation. But we do not all copy from each other; when I had worked out the scanty records of the triune Peter, I found that my labour had been in vain, for M. Charles had done it all before in his now scarce treatise on Roger Bacon, published in 1861; about that date I read M. Charles's book, and had peradventure retained some doubts of the several Petrine impersonations of this forerunner of Bacon. As an ancient ghost he is so interesting that I will set forth the little known of him. Under the name of Master Peter, Bacon describes a scholar and recluse of endowments and insight far beyond any of his time. Indeed, were it not for some independent testimony, one might suspect Bacon of



a whimsical counterfeit of himself; so strangely alike are the portraits. Peter, too, was immensely disdainful of his kind and contemporaries, immensely intolerant of sophists and rhetoricians; moreover, he was absorbed in the practice of mechanics, astronomy, chemistry, and other branches of natural science; he was devoted to experimental methods—Bacon calls him ‘dominus experimentorum’—and likewise he constructed a great burning glass. Which one of the troop of historical Peters can this rare and mysterious Peter—‘laudatus a laudato’—be? To his identity we have a clue. In more than one library of Europe, in Paris, Oxford, and Leyden among others, is extant a letter dated—in the Leyden copy—1269, at one time attributed to Bacon, but by Cave and others restored to its author, ‘Peter Peregrinus.’ The title of the letter is ‘Epistola Petri Peregrini de Maricourt ad Sygerium de Fontancourt, militem, de magnete.’ Now, Humboldt, among the medieval observers of the magnet, quotes a certain ‘Adsygerius,’ a confusion (set a-going in the Leyden catalogue of the time, I believe) of the writer of the letter with one Sygerius, to whom the letter was addressed. By the deletion of Master Adziger we advance a considerable step, for the name of this Peter Peregrinus was known to us by the quotation of this letter, which was printed at Augsburg in 1558, in the work of Gilbert on the magnet. In the letter of Peregrinus is the earliest description of the magnet pivoted in a crystal-covered box for ‘directing one’s course to towns and islands, and any places in fact on land or sea.’ But what of Peter of Méricourt, Maricourt, or Maharne-court, forms, no doubt, of the same name? In the *Opus Tertium*, where Bacon celebrates his master



Peter, he refers to him as a Picard; now in Picardy, near the ancient abbey of Corbie, is a village called Maharicourt. If then Peter Peregrinus of Maharicourt wrote in the thirteenth century on the magnet, we may safely take him to be no other than Bacon's master. But this is not all; there is substantial internal evidence of the identity. M. Charles points out that Bacon's Peter constructed a sphere to represent the movements of the heavenly bodies; now Peter Peregrinus speaks in his letter of this machine, and proposes to use a magnet wherewith to set it in motion. Finally, the Peter of Bacon and Peter Peregrinus both excelled in Optics, and rediscovered in the Middle Ages the burning glass of Archimedes, to Bacon's vast admiration. But, M. Charles reminds us, there is a profound difference between Peter and Bacon: Peter shut himself up with his machines, lived in peace, and, save for his generous disciple's tribute, died in obscurity: '*Pierre tient fermée sa main pleine de vérités, Bacon l'ouvre toute grande . . . et . . . va effronter la tempête, et entreprendre une révolution dans les idées de son siècle.*' It was well worth while, on grounds other than historical accuracy, to work out this story of Peter; if, like Goethe, he were not ethically a heroic figure, we discover in him a shadow of strange intellectual greatness, and from his story we learn how mighty men have passed over the stage of the old world, and into oblivion, without whom the mighty men we do know would never have been. Not even Roger Bacon sprang forth into the world with a Minerva birth.



