number of reaction studies too numerous to list here. Large amounts of calcium-44, iron-58 and chromium-50 have also been supplied for the production by pile irradiation of radioactive tracers which have been used in a great variety of researches. So far, 570 separate consignments or targets, ranging in size from micrograms of calcium-46 to 30 gm. of iron-56, have been dispatched to workers at Harwell and in European and Commonwealth laboratories. The output is now about two hundred consignments a year and rising steadily.

Particular emphasis has been laid by the Harwell production group on the provision of targets for nuclear bombardment from the stock of stable isotopes. It was found in early work that targets of elements heavier than magnesium could not be made by direct deposition in the separator because of sputter, and so it was necessary to use a secondary procedure. Such procedures have the advantage, moreover, of starting with a definite amount of material of known purity; providing the most efficient utilization of the stocks; and being very convenient for the users, who can request targets to suit their most varied requirements and obtain delivery within a few days. For preparation of these targets a range of techniques has been adopted including vacuum evaporation, electroplating, painting and thermal cracking, while special attention is paid to the recovery of residues without contamination. In the course of development of these methods, a useful stock of isotopic targets has also been built up.

Some work has also been done on the preparation of gas targets by direct bombardment on to metallic foils, and by this means targets containing oxygen, nitrogen or the rare gases have been made for reaction studies, while following Koch's³ technique krypton-84 has been recovered from foils for use in spectrographic discharge lamps.

The British Thomson-Houston Co., Ltd., and the Metropolitan-Vickers Electrical Co., Ltd., constructed the large separator; members of the Electromagnetic Separator Group and the Engineering Services Division of this Establishment are responsible for operation and continuing development, while the quality of the isotopically enriched samples is checked by the Mass Spectrographic and Spectrochemical Groups. Sales are made through the Isotope Division.

¹ Allen, W. D., *Nature*, **168**, 451 (1951).

² *Nature*, **166**, 1071 (1950).

³ Koch, J., *Nature*, **161**, 566 (1948).

JOHN RAY, F.R.S. (1627-1705)

By JOAN M. EYLES

JOHN RAY, the seventeenth-century naturalist, has received more attention from the historians of science than many of his contemporaries. The Ray Society has published a memoir and two volumes of his correspondence, and his life and writings have recently been treated in great detail by Dr. C. E. Raven, to whom students of Ray and his times will always be indebted. In addition, a bibliography of his works, by Dr. Geoffrey Keynes, appeared in 1951. It might seem, therefore, that little new remains to be said in this article, which commemorates the two

hundred and fiftieth anniversary of his death, on January 17, 1705. Recently, however, attention has been directed to the influence of Puritanism on the development of science in the seventeenth century¹, and the occasion provides an opportunity for outlining Ray's career in this setting, as well as to offer an amendment to Dr. Raven's conclusion that in geology Ray's outlook was "far in advance of all his British contemporaries".

John, the son of Roger Ray, blacksmith, of Black Notley in Essex, received his early education at the little grammar school of Braintree, two miles from his home and thirty miles south-east of the University of Cambridge. At that time the school was held in what is now part of the church. Ray's numerous letters throw remarkably little light on his private life; but those early grammar school days are recalled in a few dry lines in a letter he wrote to John Aubrey many years later: "Neither is y^r observation universally true that the sons of labourers and rusticks are more dull and indocile than those of gentlemen and tradesmen . . . but perchance the advantage I had of my contemporaries may rather be owing to my industry than natural parts". Ray's career was certainly built on something more than industry alone.

In 1644, as a sixteen-year-old lad, he entered the University of Cambridge, supported, Dr. Raven surmises, by a local charity intended to maintain "two or three hopeful poor scholars . . . being also of sober and Christian conversation". At that time the Parliamentary forces had already gained the ascendancy in their struggle with Charles I, and Ray's arrival at the University coincided with a period of considerable change. Many Fellows, including a dozen heads of colleges who had found themselves unable to accept the Solemn League and Covenant, were being expelled from their offices. During the ensuing Presbyterian regime, religion became something stern and colourless; the parish churches were stripped of their ornaments, and the prayer book and feast-days, including Christmas and Easter, were abolished.

John Ray himself, however, prospered, and in 1649 was elected a Fellow of Trinity College. Two years later he was accepting the usual responsibilities of a young Fellow, and acting in successive years as lecturer in Greek, in humanities and in mathematics. It is true his health was not very robust. An illness about the year 1650 had obliged him to rest for a while from serious study and take more fresh air, a pursuit that had directed his attention to the beauties of the Cambridge meadows, and set him to studying botany. He was unable to find anyone in Cambridge who could instruct him in the subject, so turned to such books as were available, and began to collect plants for "a little garden by his chamber".

In 1655 Ray's father died; and soon after, Ray seems to have arranged for the building of a house called Dewlands, at Black Notley, in which his widowed mother lived until her death in 1679. About this time he began to hold various College offices, and his action in building Dewlands seems that of a man who felt reasonably secure financially. He was not yet ordained, although in normal times it was required of most Fellows. With the return of the bishops in 1660, this was to become a pressing question with him. His earliest surviving letter, written in January 1659, indicates his views at that time. "My present condition is such that I must of necessity enter into orders, or else live at great

uncertainties, and expose myself to the mercy of men for my livelihood and continuance here. I am not resolved to enter into orders, if so be I stay here, but rather the contrary, it consisting not with those designs which I intend to pursue. Now, if I shall bid farewell to my beloved and pleasant studies and employments, and give myself up to the priesthood, and take to the study of that which they call divinity, I think it were the best way to throw myself into the country, and make such provision for this world as other men doe, and make it my business to execute the priest's office". Ray was at this time engaged in preparing his catalogue of Cambridge plants, and the advantage of a country living to one so devoted to botanical pursuits is obvious; but what he had in mind when he wrote of staying in Cambridge, but not taking orders, is not clear. Perhaps he had hopes of becoming a "Physic Fellow" in one of the colleges, which would have exempted him from taking orders. There is little information regarding the teaching of medicine in Cambridge at that time, although several of Ray's contemporaries became physicians. There had been a regius professor of physic in Cambridge since 1540, and in Ray's time this was Sir Francis Glisson, a distinguished physician; but so far as Cambridge was concerned a notable absentee. He had left Cambridge at the outbreak of the Civil War and seldom visited it.

In May 1660, Charles II was welcomed back to England by a people weary of internal wars and religious dissension. Some measure of toleration and individual liberty was promised and expected; but the Puritans, many of whom were ministers of the Church, were soon to be disappointed. We get a glimpse of the state of affairs from a letter written by Ray in September 1660: "Dr. Ferne, who is made master of this college . . . came down hither about the beginning of August, with 14 or 15 of the old gang. . . . They have brought all things here as they were in 1641: viz, services morning and evening, surplice Sundayes and holydays, and their eves, organs, bowing, going bare, feasting nights". This gives a clear indication of Ray's Puritan outlook. He wrote in the same letter: "I have long since come to two resolutions, namely, no promise of conformity, and no orders". He must have changed his mind, or been over-persuaded by friends, for three months later he was ordained in London by the Bishop of Lincoln. After this, in three different letters written in June and October of the following year, he stated his intention of leaving the College. He seems to have considered a living in Westmorland but rejected it, partly, he says, because "I find the yearly value to be lesse than it was at first represented".

In May of 1662 the Act of Uniformity received the Royal Assent and Ray knew his days at Cambridge were numbered. The Act required conformity, and a declaration that the Solemn League and Covenant had been an unlawful oath, and it was obligatory for those teaching in colleges and in holy orders. "I have already taken so many oathes & subscriptions as have taught me to disgust such pills", wrote Ray in 1662; and in August, "I shall now cast myself upon Providence and good friends. Liberty is a sweet thing. I am hampered enough already, indeed more than I would have been had I foreseen this".

On August 24, St. Bartholomew's Day, some eighteen hundred clergymen were ejected from their benefices for non-conformity, and Ray, who had quietly absented himself from Cambridge at the time, ceased to hold his fellowship.

In his hope for support and encouragement from his friends, Ray was not disappointed. In particular, Francis Willughby, 'virtuoso' and naturalist, a former student with whom he had already made two botanical tours, rallied to his aid. In 1663 Ray, Willughby and two others set off on a tour of the Continent, and to gather materials for a general natural history. It is worthy of note that the universities which they first visited—Leyden, Utrecht and Heidelberg—were all strongly Calvinistic. Willughby returned to England a year later; but Ray and another friend and former student, Philip Skippon, remained abroad until 1666. Shortly after his return, Ray made a botanical tour in Cambridgeshire and Lincolnshire with Dr. Martin Lister, who made some notes about it beginning "Mr. Wray, Mr. Dent & I went out a simpling"².

In 1667 Ray was elected to the Royal Society, and during the next five years spent much of his time travelling about England, and at intervals resided at Middleton, Willughby's home in Warwickshire. This nomadic life was brought to an abrupt halt by the sudden and unexpected death of Willughby, then only thirty-seven years of age. Willughby, however, had looked to the future of his friend, and left him an annuity of £60, which was later increased to £72 by his son, Thomas Willughby. This was a generous allowance for the time. According to the tables of Gregory King³, the average yearly income of "lesser clergymen" in 1688 was £50, and that of "eminent clergymen" £72.

Ray married in 1673, and for a few years continued to live in or near Middleton, working on Willughby's collections and notes. In 1679, when his mother died, he was living in Essex again, and he and his wife then moved into Dewlands, the house he had built and in which he was to reside until his death. His mother's will, drawn up in Ray's neat hand in 1675, shows that the blacksmith's forge was still in the family, for "all tools and utensils belonging to the shop, excepting the iron" were left to her son-in-law, John Tabor; and the rest of her goods and chattels, with the exception of 20s. to the poor of Black Notley, were to be divided between her son John and her grandchild Sarah Tabor⁴.

From now on Ray devoted himself to the preparation of his botanical works, as well as the zoological works which appeared under the name of Willughby, though Dr. Raven has shown they owed much to Ray's own researches. In 1688 an event of considerable importance to the nation, and particularly to the nonconformists, took place. James II was replaced on the throne by the Protestants William and Mary. In 1689 the Act of Toleration was passed, and this freer atmosphere was praised by Ray in a Latin preface to his "Synopsis Methodica Stirpium Britannicarum", published in 1690. "Superstition has been overthrown. Pure and reformed religion is honoured," he wrote, and in the following year he published a work entitled "The Wisdom of God Manifested in the Works of the Creation", composed largely of sermons he had delivered in Cambridge more than thirty years before. This was followed in 1692 by a more specialized work, "Miscellaneous Discourses concerning the Dissolution and Changes of the World". The latter contained Ray's geological observations and conclusions, and in later editions was entitled "Three Physico-Theological Discourses".

Ray, as Dr. Raven himself states, could go on with his natural history without consciously challenging the historicity of Genesis; but in geology he entered

the arena of conflict. Comparisons are often unfair and sometimes invidious; but Dr. Raven has stated that Ray's outlook in geology was much ahead of all his British contemporaries. These contemporaries were Robert Hooke, Dr. Martin Lister, Robert Plot of Oxford, and two men of a younger generation, Edward Lhwyd and John Woodward. They all discussed the nature and origin of fossils (Lister and Lhwyd in letters to Ray), and it is to this point that Dr. Raven gives most attention. Hooke, in time as well as in accurate and penetrating commentary, takes precedence of them all, for his statement about fossils in "Micrographia" (1665), though short, is to the point. Some account of Hooke's geological ideas, and the period to which they rightly belong, has been given by W. N. Edwards⁵ and by A. P. Rossiter⁶. Hooke's geological observations, in addition to those in his "Micrographia", are found in his Cutlerian Lecture, "De Potentia Restitutiva" (1678) and in his "Posthumous Works" (1705). The latter includes the text of two discourses delivered to the Royal Society between June 17, 1667, and September 1668. In none of these does Hooke waver from his view that fossils were genuine remains of once living creatures. Ray, on the other hand, felt obliged (as he wrote in a letter to Lhwyd in November 1690) "to settle in a middle opinion, that some are of one kind, some of another". Lhwyd answered in the same month and in the same vein: "I find in myself no sufficient ability or confidence to maintain either opinion". It is not denied, and there is abundant evidence, that Ray was anxious to believe that fossils were remains of once living things; but he had a fundamental reason for this, made clear in some pages (unnumbered but following p. 162) first inserted in the second edition of the "Discourses" (1693). "For," he wrote, "if we adhere to their Opinions who hold them [that is, the fossils] to have been original Productions of Nature, in imitation only of the Shells and Bones of Fishes: We put a Weapon into the Atheists hands". This weapon, which Ray discusses at some length, was the argument that if fossils were mere sports of Nature, produced without reason or function, then living animals, too, could be produced without "Counsel or Design". Such an argument, difficult for the modern reader to appreciate, struck at the very core of Ray's creed of divine design in Nature. For this reason, above all others, he was constrained to support the view that fossils had once been living things.

Two arguments against this, however, Ray had great difficulty in answering. One, which concerned the Deluge, will not be discussed here; the other was the fixity of species. That species might disappear he had thought "highly improbable"; but many of the fossils then being found could not be matched with living forms, and he could only hazard "that there may be some of them remaining some where or other in the Seas". Hooke had accepted the implication of extinct species; but it was this implication, more than anything else, that seems to have driven Ray to decide finally in favour of an inorganic origin for fossils. Dr. Raven has called this a recantation; but it was rather a reluctant conclusion from the evidence interpreted in the light of Ray's beliefs, evidence that had steadily accumulated as more and more ammonites and Coal Measure plants, which had no known modern equivalent, were discovered by the untiring efforts of Lhwyd, Woodward and other collectors. We can sympathize with Ray in his difficulty; but we must not overlook the clear

thinking and bold imagination of Hooke. Thus, there seems no room for doubt that it is Hooke rather than Ray who deserves Dr. Raven's encomium. It must be stressed, however, that the advances in geology were made not by the theorists but by field-workers. The latter include John Woodward, whose theories were weak, but who insisted on the importance of accurate field records.

The last fifteen years of Ray's life were spent in constant pain and illness, but his industry never slackened. He was indeed, as H. B. de Saussure wrote in 1779, "le Naturaliste le plus universel que l'Angleterre ait produit".

¹ See especially, Merton, R. K., "Science, Technology and Society in Seventeenth Century England", *Osiris*, 4, 360 (1938).

² Bodleian MS., S.C.25268, ff.421-441. quoted from Goulding, R. W., "Martin Lister, M.D., F.R.S.", Rep. for 1900 of Architect. and Archæol. Soc. of the Counties of Lincoln and Nottingham.

³ Quoted from "English Social History", by G. M. Trevelyan.

⁴ Original will at Somerset House, Comm. Ct. Lond. (E. and H.), 1679.

⁵ Edwards, W. N., "Robert Hooke as Geologist and Evolutionist", *Nature*, 137, 96 and 455 (1936).

⁶ Rossiter, A. P., "The First English Geologist", *Durham Univ. J.*, 29, 172 (1935).

OBITUARIES

Prof. H. S. Carslaw

THE death occurred on November 11 at the age of eighty-four of Horatio Scott Carslaw, emeritus professor in the University of Sydney, and Fellow of Emmanuel College, Cambridge, professor of mathematics in the University of Sydney during 1903-35. Carslaw held the degrees of doctor of science of Glasgow and Cambridge, and the honorary degree of doctor of laws of Glasgow.

Carslaw served the University of Sydney through a period of great expansion. He had precisely that balance of qualities which best fit a man to raise a small department, not very different from a 'sixth form', to a university school of mathematics with a world-wide reputation for its published work and for the quality of its graduates. He had a vigorous personality of the type around which legends collect, he was a mathematical scholar of distinction with a gift for clear exposition, and he was enthusiastic in his mathematics and aroused enthusiasm in his students.

During his tenure of the chair, the University of Sydney grew from a family affair of a few hundred students to a complex organism of four thousand students in ten faculties. In particular, this period saw the rise of the Faculties of Science and Engineering. In large measure the high standing of Sydney engineering graduates was due to Carslaw's influence on the shape of the course. His locally famous 'little book' bears the title "An Introduction to the Infinitesimal Calculus: Notes for the Use of Science and Engineering Students". His first- and second-year pass courses had very much the needs of these students in mind. The book is one of those that a lecturer likes to use as a basis for a lecture course; the text is little more than a record of leading results, there are plenty of examples, and the lecturer has scope for his own elaboration and development of the subject.

Carslaw played a large part in the development of the State (New South Wales) secondary education system, in particular in the formulation of the mathematics syllabus and its examination at the Leaving Certificate. Between 1911 and 1916 he published a series of articles and reports, under such