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JOHN RAY: INDEFATIGABLE STUDENT OF NATURE¹

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His Latin gave him a great reputation as not only the most eminent of contemporary naturalists, but in the eyes of Cuvier and Haller a principal founder of scientific zoology, ornithology, ichthyology and the greatest botanist in the memory of man.

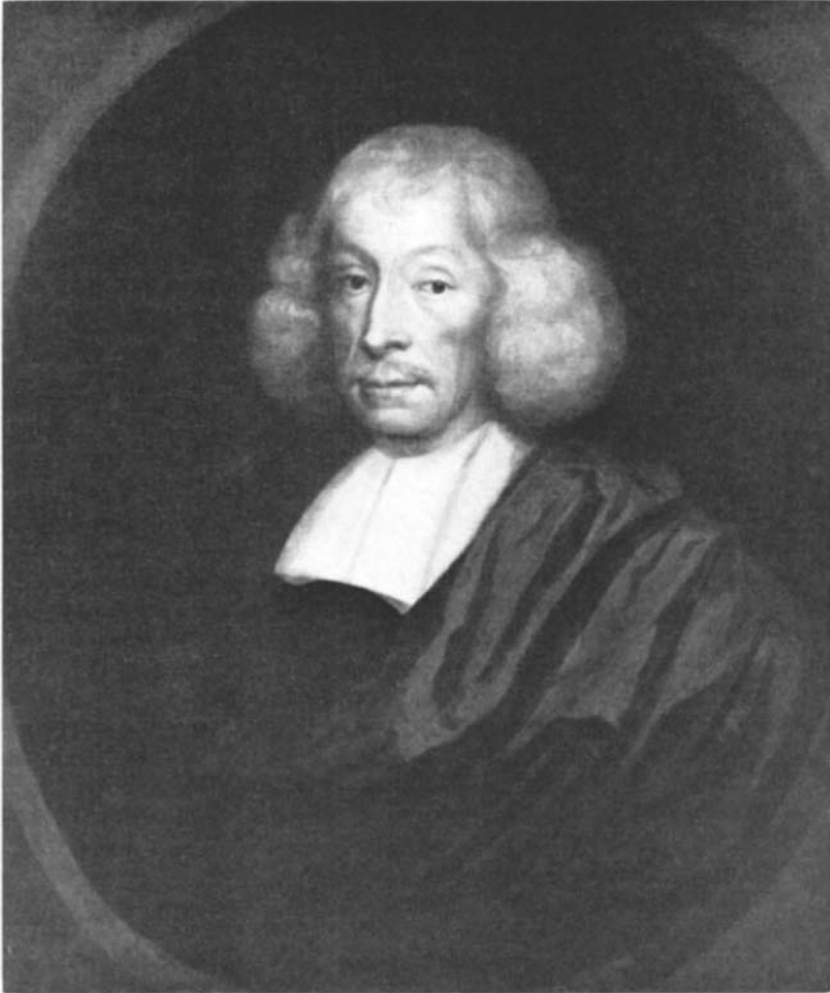
His works are the basis of all modern zoology.

Memorials of John Ray, Ray Society,
London, 1846. pp. 65, 104-6

The last half of the seventeenth century is remarkable for the number of biologists who contributed such epoch-making and revolutionary ideas to biological thought that a new era in the history of biology may be said to have dated from that period. During the previous century encyclopedic works on natural history had been published by Gesner, Aldrovandi, Jonston, and Wotton, but these were all based on the works of Aristotle and, except for Gesner, included no original observations or new concepts. The seventeenth century saw the development of knowledge based on observation and experimentation, and the beginnings of the development of the scientific method. Among the naturalists who applied these principles were William Harvey (1578-1657), the discoverer of the circulation of the blood; Anton van Leeuwenhoek (1632-1723), whose portrayal of bacteria in 1683 and of spermatozoa in 1677 are triumphs of observation with the optical means at his disposal; Jan Jacob Swammerdam (1637-1680), the first to deal with the subject of insect metamorphosis in his *General History of Insects*; Robert Hooke (1635-1703), who figured the boundaries of the cell walls of cork, and gave remarkable delineations of the insect compound eye and the larvae of a gnat; Marcello Malpighi (1628-1694), who was the first to observe the capillary circulation of the blood (inferred but not seen by Harvey) and who figured and described the structure and metamorphosis of the silkworm; Francesco Redi (1626-1697), who introduced the use of the experimental

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² The author is indebted to Canon Charles E. Raven who has given a definitive understanding and unusually detailed account of John Ray's life in *John Ray, Naturalist, His Life and Works*, Cambridge, 1942.



National Portrait Gallery, London

John Ray 1627–1705

method in discrediting spontaneous generation; and John Ray (1627–1705), who, using precise methods of observation and description, developed the first fundamental principles of the taxonomy of plants and animals.

John Ray was born November 29, 1627 at the village smith in the hamlet of Black Notley, one and a half miles south of Braintree, in Essex. He was the son of Roger Ray, the blacksmith, and his wife Elizabeth. Two older children preceded John, a brother Roger, born in 1624 (who died in childhood in 1632), and a sister Elizabeth, born in 1625. The question immediately arises: how could the son of the village blacksmith in a remote rural area obtain the necessary elementary education to qualify him for entrance to Cambridge University at the age of sixteen and a half, at a time when the boundaries between social classes were extremely rigid? The answer would seem to be that Joseph Plume, the local rector at Black Notley, who lived only a few hundred yards from the smith, recognized the talents of the young boy John and encouraged his father to send him to the grammar school in Braintree. There he acquired an excellent grounding in Latin, a beautiful and very legible handwriting, a trained memory, and an orderly mind. Samuel Collins, the Vicar of Braintree and a man of some importance, was probably influential in Ray's admittance to Trinity College, Cambridge and in his appointment to a sizarship (a Cambridge University assistantship requiring menial service) in 1644. Later, when this appointment was not forthcoming, plans had to be changed and he was finally admitted to Catherine Hall.

Ray entered Cambridge at a time when the country was in the midst of a civil war, and Cambridge had been a center of military activity since the war's beginning. Cambridge was also a center of Puritanism and was in opposition to the established Church; and in Ray's time many of the faculty were opponents of science. The curricula at the time were directed exclusively to grammar, logic, and rhetoric. Mathematics, science, and even philosophy and theology in any profound sense, were wholly lacking. Natural science was not recognized as a legitimate or profitable field of study and no laboratory of any kind existed in the University. The whole objective of education was to prepare students for the clergy and to give a classical education to the nobility.

After two years at Catherine Hall, Ray transferred to Trinity College where he was awarded a sizarship. Languages were certainly the chief study during his undergraduate years at Cambridge and he became as fluent in Latin as in English, a fluency he retained to the end of his life. Later, Ray chose Latin as the language of his publications, and his mastery of the language brought him attention not only in England but on the Continent, and gave worldwide coverage to his work.

It must have been a real struggle for the young Ray with his provincialisms of speech and rural background to acquire the language and manners of the aristocracy, and to gain the poise, dignity, and modesty which enabled him to hold an honored place in a society in which class distinctions were still almost feudally rigid.

He received his BA degree in 1647–1648 and his MA degree in 1651. An appointment to a minor fellowship in 1649 gave him the freedom to study natural history, although his time was limited by college duties. He was appointed Greek lecturer in 1651 and again in 1656, mathematics lecturer in 1653, and humanities lecturer in 1655. By this time he was already observing and collecting plants in the vicinity of Cambridge, and we find that in the autumn of 1654 he was present at the dissection of four birds: a bittern, a curlew, a yardhelp, and a duck-like bird.

It was early in this period that Francis Willughby, a young man whose name has always been most intimately connected with Ray, came to Cambridge. He was the son of Sir Francis Willughby, of Middleton Hall in Warwickshire, and Lady Cassandra, daughter of Thomas Ridgeway, first Earl of Londonderry. He was a man of delicate physique, ardent and restless temperament, and great ability and industry. Not a great deal is known regarding him, except what is written in Ray's books. His generosity in financing the travels of Ray, in giving him a home during his life, and an annuity in his will, gave Ray the courage and the means to devote himself to science. Early in their association it was agreed between the two of them that Ray would assume responsibility for the plants, while Willughby would undertake the birds, beasts, fishes, and insects.

After 1657 Ray was free of the lectureships, but served in a number of college offices: Praelector Primarius, 1657–1658, Junior Dean, 1658–1659, and Steward, in 1660 and 1661.

At the time Ray was elected a fellow in 1649, it was required in Trinity College that all fellows must be in priest's orders seven years after completing the MA. This would mean that Ray must be ordained not later than 1658. By 1660 he had not satisfied this requirement. He had a deep dislike for ritual and much sympathy with Puritanism. When he was urged to continue his place in Trinity College in 1660 he was forced to make a choice and finally decided that the invitation of the College must be accepted and that his life's work was with the University. He was therefore ordained in London on December 23, 1660; but his security with the University was short lived. During the reign of Charles II, the reactionary Parliament passed the Act of Uniformity in 1662, a law drawn up with the view of suppressing liberty of conscience. The Act decreed that all clergymen and all who held any office in the Universities must take an oath in accordance with the act, or forfeit their office. To Ray an oath was an oath and to accept the Act was to subscribe to a lie. As a man of honor, a teacher concerned with truth, he could not sacrifice truth to expediency. He could not retain his fellowship or hold any position in the Church on those terms. He refused to take the oath and resigned his offices in the College. August 24, 1662 found Ray free and without employment, a teacher with no pupils, a cleric without an assignment, prohibited by his profession from secular employment, and prohibited by law from his profession. The blacksmith's son returned to his village, a seeming failure by his own choice.

It is not clear at what point in Ray's observation of plants. His interest may have been aroused while still in grammar school at Braintree, or more likely while he was an undergraduate at Cambridge. At any rate by 1654 his explorations of the plants in the fens and woods in the vicinity of Cambridge was familiar to his friends. He made an extended trip alone on horseback in 1658, visiting Derbyshire and North Wales to observe plants and items of zoological interest. By 1660 he had written and published his first important botanical work: *Catalogus Plantarum circa Cantabrigiam nascentium*. It is this publication that gives us our first view of Ray as an entomologist. The work was not only an important contribution to botany but also includes the first published descriptions of the life histories of several insects, and demonstrates that Ray's interest in observing insects and recording in detail what he saw at first hand, antedates the agreement between Willughby and himself, whereby the former was to be responsible for the study and publication with respect to insects.

These first contributions to entomology include brief notes on the caterpillar, chrysalis, and imago of the small tortoiseshell *Vanessa urticae*, and an account of the irritability of the caterpillar of the privet hawk *Sphinx ligustri* when touched, its change to a pupa with a sheath for the projecting proboscis, and finally the moth that emerges from it. He calls attention to the mistake that Mouffet and others make in stating that the head of the caterpillar is changed into the tail of the butterfly: "in every caterpillar I have seen the exact opposite is the fact." There is an account of Mouffet's hazel-caterpillar cocoon (constructed of hair), of its pupa, and the moth, probably the pale tussock *Dasychira puribunda*, which he compares with the silkworm moth. There is a note on the luminous myriapod, probably *Geophilus electricus*, called Julus from the resemblance to hazel catkins (juli) which he says is a Scolopendra.

The subject of parasites of caterpillars occupies one of his longest notes. He begins by stating that the caterpillars of the large white *Pieris brassicae*, reared on cabbage, readily eat rape, though refusing other plants. He then states,

I shut up ten or so of these in a wooden box at the end of August 1658. They fed for a few days, and fixed themselves to the sides or lid of the box. Seven of them proved to be viviparous or vermiparous: from their backs and sides very many, from thirty to sixty apiece, wormlike animalcules broke out; they were white, glabrous, footless, and under the microscope transparent. As soon as they were born they began to spin silken cocoons, finished them in a couple of hours, and in early October came out as flies, black all over with reddish legs and long antennae, and about the size of a small ant. The three or four caterpillars which did not produce maggots after a long interval changed into angular and humped chrysalids which came out in mid-April as white butterflies.

He finally solved this problem in his *Historia Insectorum*, 1710, (p. 114):

Whence these maggots arise is a great problem. I think that the ichneumon

wasps prick these caterpillars with the hollow tube of their ovipositor and insert eggs into their bodies: the maggots are hatched by the warmth of them, and feed there until full grown; then they gnaw through the skin, come out, and spin their cocoons.

Note that in the above account he describes the appearance of the animalcules under the microscope as transparent. Ray called any lens a microscope, but never possessed an achromatic lens since these were not developed until more than a century after his death.

A note by Ray concerning the rose gall bedeguar or spangiola *Rhodites rosae* refutes the theory, mentioned by Spigel, Mouffet, and Aristotle, that beetles are born of the small maggots in the galls. Ray says: "This is incorrect. I saved some of these galls; and the maggots hidden in them through the winter came out in the following May as flies."

And finally he records his observations of the spittle-bugs:

Of the cause and origin of this foam the common crowd of philosophers is under a gross illusion; some call it star's spit and believe it rains down from heaven, like Manna and honey dew—which are found in abundance on very few plants; others that it is an exhalation from the earth; others an exudation of the plant itself. I have discovered that it is vomited from the mouth of an insect, a tiny creature that always lurks in the middle of the spittle. For if you wipe off the froth of foam, you will see for yourself the same foam very soon again poured out from the creature's mouth in such abundance that it will soon unwrap and conceal itself in it: so it can lie hid there in safety from all harm from frogs, small birds and other enemies while it is still feeble and cannot save itself by jumping or flight. This insect is almost like a louse in shape but shorter for the size of its body, yellow green in color with large protruding eyes: its hind legs are shaped for jumping, whence we are ready to agree with the learned men who have asserted by experiment that it turns into a locust such as we call Grasshopper. We, to confess the truth, have not yet investigated its origin or its final state.

This problem was also finally solved and the answer published in *Historia Insectorum* (p. 67):

The hind legs are scarcely longer than the rest: rudiments of wings appear on the shoulders: a long proboscis is bent back on the belly between the feet: they often change their skin which is found next the spittle. While they are still enwrapped in the spittle, they crawl; after leaving it, they always move by jumping, the hind feet being now stronger and longer. They resemble cicales more than locusts: they fly higher than locusts: their wings conceal their whole body.

The above observations on the life histories, metamorphosis, parasitism, and insect secretions must be regarded as the first scientific observations and precisely written descriptions of insects and their ways and means of living. As Charles E. Raven has said so well:

Ray stands out for the extent of his learning and soundness of his judgment, for his independence in rejecting traditional beliefs and demanding

proof, for the thoroughness of his observations and the accuracy of his statements. In Entomology the field was unexplored: Thomas Mouffet had left a large book based upon Edward Wotton, Conrad Gesner and his friend Thomas Penny, but is a very incomplete, ill arranged and unreliable compilation. Ray, whose concern with insects has been often ascribed to the influence of Willughby, reveals in these early notes not only a knowledge of all that had been written but the acute insight, the power of exact objective description, and the indefinable flair for a correct interpretation which are the marks of a great scientist. In a pre-scientific age, when speculation was limited by no experience of what could or could not happen, Ray's power of discarding legendary lore and fanciful explanations and of fastening upon the right line of investigation establishes for him a strong claim to be one of the fathers of modern science.

After the publication of the Cambridge Catalogue, Ray made another exploratory journey, this time with Willughby as companion. Their itinerary took them to North England and the Isle of Man. This was apparently the beginning of the partnership between Ray and Willughby that resulted in the expansion of Ray's interest to zoology as well as botany and ultimately led to his editing and publishing Willughby's notes on ornithology and ichthyology and his own works on mammals and reptiles and insects.

A third exploratory trip was made to Scotland from July 26 to September 7, 1661 with a former pupil, Philip Skippon. The record of this trip includes not only the plants, but also a list of fish seen, and a description of the soland geese, the scout, the cattiwake, the scart, and the turtle dove. A comment on the mores of the time gives us a glimpse of the general superstition that existed, "At the time we were in Scotland divers women were burnt for witches, to the number of about one hundred and twenty."

A fourth journey, around Wales, was made May 8 to July 24, 1662. His companions were Willughby and Skippon. A previous journey had involved visits to famous churches and castles, but Willughby's enthusiasm for field observations of animals resulted in most of the time being spent in exploring little known islands and bits of coast where sea birds and rare plants were the prime objects of interest. The two friends were in agreement that for the naturalist, the study of museum specimens and the literature must be subordinated to personal observation and knowledge of the organism in its native habitat. Ray held to this principle until his death. At the end of the journey Ray returned to Cambridge, refused to take the oath required by the Act of Uniformity, resigned his fellowship at Cambridge, and returned to Black Notley.

The winter of 1662-1663 he spent at Saxmundham in Suffolk as a tutor in the home of Mr. Thomas Bacon. This was only a stop gap, since Willughby had proposed an extended journey on the Continent that began on April 18, 1663 when Ray, Willughby, Skippon, and Nathaniel Bacon (probably not the son of Thomas Bacon) met at Dover and proceeded to Calais. The record of this three year sojourn in Europe was published in 1673 with the title "Observations in the Low Countries." They visited Belgium, the

Netherlands, Germany, Switzerland, and Italy. By March 1664 they had visited many points in Italy and had arrived at Naples. Here the party divided, Willughby and Bacon staying in Naples, Ray and Skippon going on. Willughby spent the summer of 1664 in Spain and then returned to England. Ray and Skippon remained in Italy until March 1665 when they went to Switzerland and France and did not return to England until the spring of 1666. Ray devoted a great deal of time during these two years studying and collecting plants, birds, fishes, and stones. The winter of 1664 he attended lectures on anatomy given at the University of Padua by Pietro Marchetti. He visited the Museum of Aldrovandi and attempted to see Malpighi, but he was absent from the University of Messina. He also made observations on a comet and visited natural historians in the universities of the Low Countries, Germany, Italy, and France. All this was to serve him well in the years ahead, for during the last years of his life after 1679, he rarely left Black Notley.

In the years following the European tour, Ray devoted much of his time with Willughby to arranging the material they had gathered. In 1667 he and Willughby made a journey to the west of England. He was in London on November 7 when he was elected to the Royal Society. The years 1668 and 1669 were devoted to the writing of the *Catalogus Plantarum Angliae*, published in 1670 and dedicated to Francis Willughby. It was at this time that Ray changed the spelling of his name. While at Cambridge in Trinity College and thereafter, he spelled it "Wray," but in a letter to Martin Lister August 22, 1670 he announced that he was returning to the spelling "Ray," used by his forefathers.

His last journey for collecting materials began in July 1671 when he traveled to the north for the purpose of observing plants in the field. In late May 1672 he was planning a further journey to the west country when his plans were abruptly ended by the death of Willughby on July 3 in his 37th year. This was an even greater blow to Ray than the loss of his fellowship at Cambridge ten years before. Willughby was a man of high ideals, sensitive, alert, and energetic. By birth and training he belonged to the world of politics and society, and had an interest in government and education, all outside of Ray's concern. His chief interest in natural history was the insects, but he, together with Ray, did much field work and dissection of birds, mammals, and fishes. Ray left the insects largely to Willughby, and shared with him the others, dissecting a bird and mammal at Padua, a porpoise at Chester, and fishes at various times and places.

Ray had been a member of the Willughby household since their return from the Continental tour. His position there had been easy. It was the custom of the day for every large land owner and most of the smaller squires to have a resident chaplain. Willughby was conforming to custom when he invited Ray into his home. After Willughby's death, his mother, Lady Cassandra, apparently saved Ray from considerable unpleasantness, but Mrs. Willughby seemingly had no scruples about putting him in his place. Willugh-

by's will made Ray one of five executors, and in addition he was given the responsibility for the education of Willughby's two sons, and an annuity of 60 pounds a year. The responsibility of publishing Willughby's work was an even greater tie. "I am," he wrote in a letter from Middleton, "like now to set up my staff here, at least so long as my old lady (Lady Cassandra, Willughby's mother) lives."

Following Willughby's death Ray assumed the responsibilities laid upon him by Willughby's will: the duties of an executor and the education of the children. Within a year he married, Margaret Oakley, with Mrs. Willughby's permission, a member of the Willughby household, on June 5, 1673. His life in the Willughby household was less than pleasant. The widow Willughby had no interest in the scientific interests of her husband nor his scientific friends. When Lady Cassandra died on July 25, 1675 a change was made at once; Mrs. Willughby removed the children from Ray's responsibility and made it impossible for Ray and his wife to continue living at Middleton. After a brief stay at two different locations, and following the death of his mother on March 15, 1679, the Rays returned to Black Notley where they remained until Ray's death.

After Willughby's death Ray set himself the goal of producing books on birds, fishes, mammals and reptiles, and insects, as well as botany. As early as 1674 he was already working on the birds. Willughby's notes formed the basis of this work, but Ray had shared with Willughby in the field work and enlarged on Willughby's notes by including his own personal observations and the writings of other students of birds, and he proposed a classification of outstanding merit. It was customary until 1844 to regard Ray as merely the editor of the book. It is now known that Ray spent an immense amount of time organizing the undigested notes of Willughby, adding knowledge of his own, substituting his own classification for Willughby's, and skillfully editing the whole. It is characteristic of Ray's modesty and his loyalty to his friend that he presented it for publication to the Royal Society with Willughby's name as author, and that during his lifetime he spoke of it as Willughby's *Ornithologia*. It was published early in 1676.

The move from Middleton to Black Notley enabled him to devote twenty years to study and writing. The *Methodus Plantarum* was published in 1682 and Willughby's *Historia Piscium* in 1686. The latter was begun immediately upon the publication of the *Ornithologia*. It may be that during the last year at Middleton he organized Willughby's notes and wrote some of the manuscript. After the break with Mrs. Willughby it was difficult for him to get Willughby's papers, and the evidence at present indicates that almost all of his book is Ray's work. His loyalty to Willughby and the memory of his stimulating and energetic cooperation compelled him to publish the *Historia Piscium* as a posthumous work. Ray was evidently a man who deeply appreciated any kindness or consideration and was perhaps overzealous in showing his gratitude and acknowledging obligation. Willughby had given him a home when Cambridge and the Church had rejected him and Willughby had pro-

vided in his will the means to carry on his research and to devote the rest of his days to science. He felt bound to honor his friend and co-worker with the authorship of the *Ornithologia* and the *Historia Piscium*. He must have felt that this was the least he could do after their agreement that Ray would be responsible for plants and Willughby for the birds, mammals, fish, and insects. The book has its defects, due to the condition of knowledge at the time, but where it is based upon first-hand knowledge it is regarded as remarkably accurate. The descriptions are a tremendous improvement over those of his predecessors; this was acknowledged by Cuvier when he wrote "they are often more accurate and intelligible than those of Linnaeus." It may be said that, considering Ray's lack of time and material, the ignorance of anatomy, habits, and classification of his day, the difficulty of procuring material, and the pressure of his work on plants, the *Historia Piscium* is an outstanding achievement.

Four daughters were born to the Rays: the twins, Margaret and Mary, August 12, 1684; Catherine, April 3, 1687; and Jane, February 10, 1689. In later years these children were active cooperators in the gathering and rearing of insects that provided much of the information for the *Historia Insectorum*.

The last great works on plants were the *Methodus Plantarum* in 1682, the three volumes of *Historia Plantarum* in 1686, 1688, and 1704, and the *Synopsis Britannicarum* in 1690.

Having completed his great works on plants, and having honored his responsibilities to Willughby with the *Ornithologia* and the *Historia Piscium*, Ray now turned to the mammals and reptiles. The *Synopsis Animalium Quadrupedum et Serpentinum Generis* was started in 1690 and published in 1693. Very little is known of the circumstances which encouraged Ray to undertake this work, but since the book reveals his extensive knowledge of the literature of physiology and comparative anatomy, and a long experience of observation and dissection of the mammals, including the dissection of the human body, he must have long contemplated producing a work in this field of zoology. The book includes a classification that marks a great advance; he discusses spontaneous generation (which he emphatically rejects) and makes extensive use of comparative anatomy, which prompted Cuvier to claim that he was the first zoologist to make use of this field of science. He discusses the problem of defining "what is an animal" and deals with the question of whether individual animals were each created in the beginning or are constantly produced by fresh generation, and are animalcules which are increased and perfected by generation situated in the ovum of the female or the sperm of the male. The two latter problems are discussed at length but he readily admits, "To be frank, many doubtful points can be mooted which I confess myself unable to solve, not because they do not have definite natural causes but because I am ignorant of them." His discussion of classification rejects the distinction of animals into viviparous and oviparous because it is inadequate, stating that all animals come from eggs and describing the differences between the eggs of the two groups.

In the early days of his fellowship at Cambridge one of his duties was to address the chapel at stated intervals. These addresses or sermons were known as "commonplaces." In these he began to develop the principles and philosophies which finally resulted in the published work *The Wisdom of God Manifested in the Works of Creation*. This was probably the most popular and influential of Ray's works. The first edition of 500 copies was a small volume of 249 pages. It was reprinted in a second edition of 382 pages in 1692, a third edition of 414 pages in 1701, and a fourth edition of 464 pages in 1704. A French edition came out in 1714 and a German edition in 1717. Altogether 16 editions appeared before the end of the eighteenth century and two more appeared during the nineteenth.

Ray had discussed the structure and functions of the living organism in the introductory essays of *Historia Plantarum* and *Synopsis Quadrupedum*, going from comparative anatomy to physiology and behavior, but he had not gathered together and organized the results of his studies, nor had he attempted to explain life in the terms of science and philosophy. *The Wisdom of God* abounds with references to and discussions of problems ranging from the nature of atoms or the influence of the moon upon tides to those of the shape of bee's cells, the movements of birds and fishes, the structure of the eye, and the growth of the fetus in the womb. With each edition he enlarged the book with additional observations and inductions.

He mentions the importance of air for living things: that fishes die in a sealed vessel, that insects breathe through many orifices on each side of their bodies (spiracles) so that if these are stopped with oil or honey the insect dies, and that plants have a kind of respiration, as discovered by Malpighi.

Of entomological interest is his full account of the comb and cells of the honey bee and of the ant, "which as all naturalists agree hoards up grains of corn for the winter and is reported by some to bite off the germen of them lest they sprout: which I look upon as mere fiction; neither should I credit the former relation, were it not the authority of scripture, because I could never observe any such storing up by our country ants."

It is impossible in this brief treatment to list all the scientific statements and arguments that Ray brings up in his book when dealing with animal and plant physiology, the usefulness of animals and plants to man, the character and properties of the earth, planets, sun and stars, his discussion of the human body, and numerous other topics. We would, however, call attention to a statement by Ray concerning the principles that should guide one in scientific investigations:

It may be (for aught I know and as some divines have thought) part of our business and employment in eternity is to contemplate the Works of God. . . . I am sure it is part of the business of a Sabbath Day. . . . Let it not suffice to be book learned, to read what others have written and to take upon trust more falsehood than truth, but let ourselves examine things as we have opportunity, and converse with Nature as well as with books. . . . Let us not think that the bounds of science are fixed like Hercules his pillars and in-

scribed *Ne plus ultra*. The treasures of nature are inexhaustible. . . . I know that a new study at first seems very vast, intricate and difficult; but after a little resolution and progress, after a man becomes a little acquainted, as I may say so, with it, his understanding is wonderfully cleared up and enlarged, the difficulties vanish, and the thing grows easy and familiar Some reproach methinks it is to learned men that there should be so many animals still in the world whose outward shape is not yet taken notice of and described, much less their way of generation, food, uses, manners, observed. If man ought to reflect upon his Creator the glory of all his works, then ought he to take notice of them all and not to think anything unworthy of his cognizance.

It has been said that the *Wisdom of God* more than any other single book initiated the true adventure of modern science and is the ancestor of the *Origin of Species* and *L'Evolution Creatrice*.

One last project to which Ray had dedicated himself on leaving Cambridge and one which his friend Dr. Tancred Robinson was continually urging him to complete was the history of insects. In the beginning he had left the insects to Willughby, but nevertheless he made notes of observations of his own, and so in 1690 he turned to the work on entomology. He was now 63 years old, in poor health, made miserable by constant pain and sleeplessness due to ulcerations of his legs. While he collected and noted a considerable amount of material himself, he had no access to collections or manuscripts after he left the Willughby home and settled in Black Notley. He was not lent Willughby's notes on insects until the last year of his life, but he incorporated them into his manuscript in full. The only literature available on the subject was Jan Jacob Swammerdam's *General History of Insects* (1669), which Ray regarded as the best book ever written on the subject; the work of Johan Goedart, whose notes and plates had been edited and published by Ray's friend, Martin Lister; and Mouffet's *Insectorum Theatrum*. We might say that he had to start from scratch. Here then is Ray, the entomologist, who in the last fourteen years of his life, with the help of four little daughters, reared and described the life cycle of nearly three hundred local Lepidoptera.

We find him during these years collecting specimens, rearing countless insects, and recording his observations. All of this was accomplished in his own home, where he encouraged his children to participate in gathering and rearing material, and with the help of Thomas Simpson, who apparently was in Ray's employ. The exploits of the children are frequently recorded in the published work, and several of the reared insects are named for them, "Katherine's Eruca, Jane's Chickweed Caterpillar, etc." His wife is connected with a notable observation describing a moth (*Pachys betularia*). He writes: "it emerged out of a stick-shaped geometer caterpillar; it was a female and came out from its chrysalis shut up in my cage; the windows were open in the room or closet where it was kept, and two male moths were caught by my wife who by a lucky chance went into the room in the night; they were attracted, as it seems to me, by the scent of the female and came from the

outside." This was first known record of assembling, and Ray hit on the correct explanation of it the first time. Insect scents with the power of attraction have now been chemically identified and termed "pheromones," a popular topic for entomological symposia.

Ray must have had an unusual ability to arouse the enthusiasm of his family, his gardner Simpson, and also the neighbors for his project and he managed to maintain their interest and cooperation in contributing material over the years. It is to be regretted that Ray himself, more or less bedridden, had to depend on others to such a great extent. We miss the talent for observation in the field that characterized his active, earlier days. Two examples will illustrate this point, both quoted from his published work.

On the 22nd June, 1667 I saw a Wasp, one of the largest of his tribe—I do not now recollect the species—dragging a green caterpillar three times longer than itself . . . Before my very eyes it carried it almost the full length of a measuring rod, that is some fifteen and one-half feet; and then deposited it at the mouth of a burrow which it had previously dug for itself. Then it removed a ball of earth with which it had sealed up the entrance; went down itself into the hole; after a brief stay there came up again; and seizing the caterpillar which it had left near the opening carried it down with it into the burrow. Soon, leaving it behind there, it returned alone; gathered pellets of earth and rolled them one by one into the burrow; and at intervals scratching with its fore feet, as rabbits and dogs do, flung dust backwards into the hole. It kept repeating the same operation with dust and pellets alternately until the burrow was completely covered up; sometimes it descended in order, as it seemed to me, to press down and solidify the soil; once and again it flew off to a fir tree nearby perhaps to look for resin to stick the soil together and consolidate the work. When the opening was filled and leveled with the surface of the ground so that the approach to it was no longer visible, it picked up two pine-needles lying near and laid them by the burrow's mouth, to mark, as is probable, the exact spot. Who would not wonder in amazement at this? Who would ascribe work of this kind to a mere machine.

This was originally published in Philosophical Transactions [6(76):2280–81] October 26, 1671, two hundred years before Fabre!

Another example from about the same period, signed F. W. but observed by both Willughby and Ray and written by Ray, concerns the leaf-cutter bee (*Megachile willughbiella*).

These bees fashion sections of rose leaves carefully rolled up and stuck together into cylindrical chambers: they might be called "Cartrages" in English from the exact resemblance they bear to the paper wrappings filled with gunpowder used for the larger guns; in the trunks of willows soft and decaying they dig cylindrical burrows exactly the size of these capsules; these burrows run up or down following the grain or fibre of the wood, never across it; the capsule is placed at the bottom of the burrow, or at the top if the burrow runs upward, and exactly fills the space, the round end of the capsule touching the bottom of the burrow; at the concave end of the capsule the round end of another capsule is tightly fixed; and so, five, six, or seven capsules, one upon another, are found in a single burrow.

By 1690 when he began the preparation of his work on the insects, personal field observations were no longer possible because of his poor health. Thus he turned to description and classification of the material he had collected over the years and the specimens that his friends and correspondents sent him. He was fully aware of the difficulty that he faced with respect to classification. The only proposal for insect classification existing when he started his work was that of Swammerdam, who had studied and described metamorphosis and suggested it as a basis for classification. Ray was therefore breaking new ground; he was aware of Swammerdam's work, but even so he writes of the uncertainties and lack of knowledge that made the problem so difficult. He had gained considerable experience in his work on the *Historia Plantarum*, the *Ornithologia*, the *Historia Piscium*, and the *Synopsis Quadrupedum*; now during the last years of his life he would attempt a history of insects. That he realized the difficulties is evident from a letter to Edward Lhwyd, July 7, 1690:

Reviewing my notes concerning insects and considering the things themselves I find it a thing of infinite difficulty to draw up any tolerable epitome of the History of such as are found with us; they being almost innumerable. The two great heads or Summa genera that I would divide them into are 1. *Quae nullam subeunt mutationem*. (Those without metamorphosis). 2. *Quae metamorphosis aliquam petiuntur*. (Those undergoing some metamorphosis). The second genus I may divide either as they appear at their first hatching from the egg, and so they will be either *Polypoda, erucæ*; or *Hexapoda*; or *Apoda, eulæ*. Of the first sort come Butterflies; of the second Beetles, of the third Flies of all sorts, Bees, etc. Or 2, as they appear after they have undergone their last change, and so they may be subdivided into *Coleoptera*, Beetles, etc. or *Anelytra* which are either *alis farinaceis, Papiliones, or alis membranaceis pellucidis*, and those either *Tetraptera*, Bees, Wasps, Hornets, etc. or *Diptera*, Flies, Gnats, etc. I am yet doubtful about the process of *Locustæ forficulæ* and *Cimex sylv.* which though winged insects, yet I suspect undergo no metamorphosis. Howbeit they are not at this first exclusion winged, but their wings grow out afterward.—I am doubtful concerning ants whether the flying may not be the males, the creeping the females; for they are found together in the same hills. Neither am I yet full satisfied concerning the flying and creeping Glow-worms. The number of *Erucae* alone in this island is incredible, some plants having three or four sorts feeding upon them; and if we should make the *Papiliones* a distinct genus from them, as all that write the History of Insects have done, we should double the number of species. The Beetle-tribe I hold to be no less numerous than they; and the Flies perchance more. So that I know not but that the species of insects may not be equal to or exceed those of Plants.

Here is the first recognition of the enormous number of existing insects and the complications issuing therefrom in bringing order to the knowledge about them. Here, also, are the beginnings of the classification that was published in 1705 in *Methodus Insectorum* and later reprinted in the *Historia Insectorum*.

It appears that from the beginning Ray planned to include Willughby's notes on insects in writing the *Historia Insectorum*, but he had long ago sent

Willughby's papers to his son, Sir Thomas Willughby, and he now requested the loan of the notes on insects to make the book on insects more complete. At first he was unsuccessful, but they finally arrived in 1704 at about the time he finished the *Methodus Insectorum*. So in August 1704 he set for himself the task of completing the history of insects. He realized that he might not live to finish it, but he determined to leave it in such a state that an editor would not find it difficult to arrange for publication.

In the five month period after he received Willughby's notes, Ray had produced a manuscript which, while incomplete, was in such a state that it could be edited for publication. Unfortunately, this was not to be. He died on January 17, 1705. A few days before his death the collections and manuscript were sent to Samuel Dale of Braintree, who had been an assistant and cooperater in Ray's studies of insects. Dale was urged by Hans Sloan to undertake the editing, but he declined. The script was then taken by William Derham. He kept the papers until the summer of 1708, having done nothing with them, and then sent them to the Royal Society. After more than a year's delay the *Historia Insectorum* was published in 1710, with no sort of preface or explanatory note.

A critique and description of the contents of *Historia Insectorum* has been given by Charles E. Raven in his book *John Ray, Naturalist, His Life and Works*. Raven comments that "The book is a medley, an unedited collection of material, such as any author undertaking a piece of research amasses before the final drafting of his work. The *Methodus*, or scheme of classification, published as a sixteen page pamphlet in 1705, was reprinted as an introduction; but in the book itself this arrangement is very loosely followed." Sections on certain groups contain only notes, sections on other groups contain lists of species with short descriptions, and some sections contain attempts at classification. Ray's treatment of the butterflies and moths illustrates the principle which guided him in the study of insects: to consider the biology and structure of the whole insect from egg to adult. Raven has pointed this out with respect to the moths:

Here Ray evidently felt that he was breaking new ground; for in fact, apart from a few large and brightly colored species, they were then almost entirely unknown. No one hitherto had even collected them seriously; no one had ever realized the importance of studying their metamorphoses and working out full descriptions of each stage. He seems to have grasped what Lepidopterists for one hundred and fifty years after him were slow to appreciate that, if a true understanding of these insects or a correct classification were to be obtained, it was not enough to amass collections of the imagines. From Linnaeus down at least to Haworth the perfect insect alone was regarded as furnishing characters for the division and subdivision of groups, and a study of the earlier stages was virtually ignored. Here as elsewhere Ray reveals a scientific endowment, a sense of the wholeness and continuity of life and a flair for the right method of approach, which was centuries ahead of his time. Where he has completed his task and brought together descriptions of larva, pupa and imago, his records can easily be identified; if he had been able to

carry forward his work or even to arrange the material actually gathered, he might have saved entomology from a vast amount of superficial and mistaken classifications. He would have done for insects what he did for plants—start future students upon the study of the organism as a whole, open up and provide material for a thorough appreciation of taxonomy, and save us from being afflicted with arbitrary and fanciful systems of classification and nomenclature. If only the Royal Society or some of his wealthy friends had realized the mass of material that he had assembled, and recovered from Dr. Dale the boxes of insects to which his notes so carefully refer, and had plates made from them so that each description might have its appropriate illustration, a century of pioneering could have been saved and Ray's own inimitable work been made available. As it is the History remains a locked museum, known indeed and studied by Linnaeus, but replaced in public esteem and general utility by Petiver's very inferior junk-shops, and Eleazar Albin's picture-books.

From the standpoint of entomology it is unfortunate that Ray did not undertake the *Historia Insectorum* until the last years of his life when he was chronically ill, confined to his house a large part of the time, and dependent upon others for aid in his observations of the insects which he so carefully reared. However, considering his devotion to the study of plants which was his first love, and that his major work in that field was published in three volumes over a period of years from 1686 to 1704; his loyalty and devotion to Willughby which compelled him to give his attention to the *Ornithologia* and the *Historia Piscium* immediately after Willughby's death; the fact that he had to begin on an entirely new basis since Willughby's notes on insects were not made available to him until the year before his death, it is apparent that he could not have done otherwise. In fact, his illness and confinement to his home are probably responsible for the devotion of his last years to the insects, since these he could rear and observe in his own home, and his family and friends could, without great effort, supply him with material. We can only speculate that if entomology had been a major interest in his early years, his insistence on observing the whole animal in its natural environment, his genius in interpreting what he saw, and the ability to describe it clearly and succinctly, would have resulted in an epoch making *Historia Insectorum* that would have wielded tremendous influence on later investigators.

THE PERSONAL LIBRARY OF JOHN RAY

There is no evidence that Ray was himself a book collector, though he necessarily possessed a considerable working library. His books were for use and they sometimes suffered in consequence, even when they were borrowed copies. In the year 1699 he had to write to Dr. Hans Sloan: "Your Herman's 'Parad. Bat.' and Boccone's two books I intend to remit by next week's carrier, with thanks for the use of them. I must beg your pardon for having in some measure defaced them . . . by sullyng them myself, being forced to use them by the fireside, and partly by a child's unluckily scattering ink upon them." Conditions at Black Notley were evidently not always favorable to the care of books. Nevertheless, at his death, Ray's widow found herself in pos-

session of a library of some value, with which she was able to relieve her straightened circumstances. In 1704 she wrote to Dr. Hans Sloan: "I do intend to dispose of Mr. Ray's books and will get Mr. Dale to make a catalogue of them which shall be sent to you, as likewise an account of what papers Mr. Ray left and doubt not your assistance therein."

The books were sold in March 1708 by Ballard, and a copy of the catalogue is preserved in the British Museum [S-C. 326.(6)]:

Bibliotheca Rayana: or, a Catalogue of the Library of Mr. John Ray, Late Fellow of the Royal Society. Consisting of very valuable Greek, Latin, French, English, etc. Books, in Divinity, Physick, Philosophy, Philology, History, etc. in all Volumes, and of the most Celebrated Editions of Aldus, Stephanus, Elzvir, etc., several on large Paper, gilt Back, etc. Which will be sold by Auction, at the Black-Bay (alias Latin) Coffee House in Ave-Mary-Lane, near Ludgate Street, on Thursday, the 11th of this Instant March, 170- $\frac{7}{8}$, beginning every evening at Five-o'clock, till the sale is ended. By Thomas Ballard, Bookseller. Catalogues may be had. . . .

Each of Ray's books is listed separately in the catalogue, and the width of his interests and reading is fully demonstrated. The total number of volumes in Latin, French, Italian, and English is 1350, including 284 in folio. Ray's mind, however, was serious and did not allow him much recreation with the English poets, the only representatives of lighter literature being Chaucer (1602), Donne (1650), Cowley (1656), and Quarles (Argilas and Parthenia).

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