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ATTENDING TO INSECTS: FRANCIS WILLUGHBY AND JOHN RAY

by

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Francis Willughby and John Ray were at the forefront of the natural history of insects in the second half of the seventeenth century. Willughby in particular had a deep interest in insects' metamorphosis, behaviour and diversity, an interest that he passed on to his friend and mentor Ray. By examining Willughby's contributions to John Wilkins's *Essay towards a Real Character* (1668) and Ray's *Methodus insectorum* (1705) and *Historia insectorum* (1710), which contained substantial material from Willughby's manuscript history of insects, one may reconstruct how the two naturalists studied insects, their innovative use of metamorphosis in insect classification, and the sheer diversity of insect forms that they described on the basis of their own collections and those of London and Oxford virtuosi. Imperfect as it was, *Historia insectorum* was recognized by contemporaries as a significant contribution to the emerging field of entomology.

**Keywords: insects; entomology; natural history; observation;
metamorphosis**

INTRODUCTION

The relative contributions made by John Ray and Francis Willughby to the series of zoological works that Ray published, mostly under Willughby's name, after the latter's untimely death in 1672, have long been disputed.¹ Since Charles Raven first published his biography of John Ray in 1942, the prevailing view has been that Ray was the leading partner in their collaboration and that Willughby—younger, wealthy, amateur—chiefly provided financial support. Raven asserted that it was 'mistaken' to 'give Willughby the credit' for the histories of birds, fishes and insects. Ray 'created out of a few incomplete memoranda a series of books, each of which marked a new epoch in its special field.' In short, 'it [is] certain that Ray was a scientist of genius and probable that Willughby was a brilliantly talented amateur.'²

Other scholars have been more judicious, and less willing to distinguish between genius and mere brilliance. William Stearn has called attention to the early collaboration between Carl Linnaeus and Peter Artedi, who planned to divide up the natural world between them

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‘like Ray and Willughby earlier.’ Like Ray and Willughby, Linnaeus had to carry on alone after Artedi drowned in an Amsterdam canal in 1735. Stearn emphasizes the importance of Artedi’s research and the stamp he left on Linnaeus’s later work.³ Although Stern, a botanist, did not try to disentangle Ray’s and Willughby’s contributions to the zoological works, his analogy has inspired this paper in two ways. First, I argue that Willughby was far more than Ray’s companion and Maecenas, but that he, too, was a serious student of natural history. Decades after Willughby’s death, Ray’s approach to zoology was shaped by the two men’s joint investigations in the 1650s and 1660s. Second, I wish to explore the nature of their common zoological interests: the kinds of phenomena that interested them, their working methods in investigating nature and their relation to their predecessors and contemporaries.

My exploration of these two aspects of their zoology focuses on insects. Insects received relatively little attention from Renaissance and early seventeenth-century naturalists.⁴ Thomas Moffett’s *Insectorum sive minimorum animalium theatrum*, based largely on material from Edward Wotton, Conrad Gessner and Thomas Penny, was substantially complete by 1590, but it did not appear in print as a whole until 1634. Ulisse Aldrovandi’s *De animalibus insectis* (1602) was the first book in print devoted entirely to insects, and some parts of Moffett’s manuscript appeared in Edward Topsell’s *Historie of serpents* (1608). John Johnston published a derivative insect book in 1657. When Ray and Willughby turned their attention to insects in the 1650s and 1660s, they were joining a relatively small group of naturalists, far fewer in number than those who pursued botany or the study of quadrupeds or birds.

The publication in the 1660s of several important works would change that: Johannes Goedaert’s *Metamorphosis naturalis* (1660–69), Robert Hooke’s *Micrographia* (1665) and Jan Swammerdam’s *Historia generalis insectorum* (1669) bear witness to a new interest in insects and inspired further study. However, they were not Willughby and Ray’s inspiration, for the two friends had already been observing insects in the 1650s. Their observations and descriptions were significant. *Historia insectorum* (*History of insects*), published posthumously under Ray’s name, was recognized by eighteenth-century scholars as a foundational work. Ray testified on several occasions, moreover, that insects were Willughby’s chief interest and that he had made interesting observations about them. The publication history of *Historia insectorum* allows us to reconstruct, even in the absence of related manuscript material, much about Ray’s and Willughby’s interests and methods. In short, we learn much about these particular late seventeenth-century naturalists, and about new developments in the study of insects, by studying how they attended to insects.

RAY, WILLUGHBY AND INSECTS

John Ray and Francis Willughby were closely associated from the time that Willughby matriculated at Trinity College, Cambridge, in 1652 as a Fellow Commoner, to Willughby’s departure in 1660. During that time, as Richard Serjeantson has recently shown, Willughby took an uncommon interest in learning for a Fellow Commoner; these sons of the wealthy gentry and nobility did not generally take their studies seriously, and they rarely took degrees. Willughby did: a BA in 1655 and then an MA in 1659, probably an earned one.⁵ Although Willughby was often called a ‘mathematician’ in his lifetime,

his studies ranged widely, and he took a keen interest in natural history. In his *Observations* on his and Willughby's continental travels, published in 1673, Ray wrote:

What Birds, Beasts, Fishes and Insects I observed abroad, whether common to us in England, or peculiar to other Countries, I have forbore to set down, because the taking notice and describing of them was the particular design and business of that excellent person Mr. Francis Willughby lately deceased; and he having prepared store of materials for a History of Animals, and likewise digested them into a convenient method, that work (if God grant leisure and ability to bring it to due perfection) is intended to be made public, and the Reader may there find what is here omitted.⁶

Writing to Henry Oldenburg on 30 November 1674, Ray remarked, 'The History of Insects is that wherein Mr. Willughby did chiefly labour and most considerably advance; which yet for some reasons I reserve for the last.'⁷ Those reasons are obscure, although Anna Marie Roos has suggested that Ray may not have wished to compete with Lister's *Historia animalium*, which would be published in 1678.⁸ In the preface to *The Ornithology of Francis Willughby*, Ray wrote:

Viewing his [Willughby's] Manuscripts after his Death, I found the several Animals in every kind both Birds, Beasts, Fishes, and Insects digested into a Method of his own contriving, but few of their Descriptions and Histories so full and perfect as he intended them; Which he was so sensible of, that when I asked him upon his death-bed, whether it was his pleasure they should be published, he answered, that he did not desire it, nor thought them so considerable as to deserve it, or somewhat to that purpose, for the very words I do not well remember, though he confest there were in them some new and pretty observations about Insects.⁹

Ray was not simply honoring Willughby's memory while working at Middleton on the first part of his legacy. Writing to Lister in October 1668, when Willughby was still alive, Ray explained he had avoided spiders because he had never got over his childhood fear of them. 'I have not wholly neglected', he added, 'other genera of insects, both coleopterous and without elytrae. But since Mr. Willughby had painstakingly devoted himself for many years to acquiring, examining, describing, and comparing them, I have studied them only occasionally, as a pastime [*animi causa*].'¹⁰

In short, in their natural history collaboration, Ray's attention to insects was occasional; Willughby's was profound. In his 1660 catalogue of Cambridge plants, Ray praised Willughby's learning in botany and every field of literature. But in the text he cited Willughby once, in a lengthy passage on the anomalous generation of certain caterpillars.¹¹ Willughby had been studying caterpillars that sometimes turned into chrysalises and butterflies, and sometimes into little worms that spun cocoons and later emerged as flies; Ray wrote that the two of them hoped to make further observations in the coming spring. In the following year Willughby read a paper to the Royal Society on insects' reproduction.¹² The friends' close collaboration implies that Ray's later approach to insects may well have been shaped by the interests of his young companion. A letter that Ray wrote to Derham in August 1704, near the end of his life, is suggestive: Ray explained that he was persisting with *Historia insectorum*, despite his health,

because I have Mr. Willughby's History and Papers in my hands, who had spent a great deal of time, and bestowed much pains, upon this subject, when there were few that

minded, or were diligent and curious in it, though now there be many, and it is pity his pains should be lost.¹³

WILLUGHBY'S PUBLICATIONS ON INSECTS DURING HIS LIFETIME

After the observations reported in Ray's Cambridge catalogue, Willughby's next significant published contribution to natural history was his succinct but wide-ranging contribution to the classification of animals for John Wilkins's *Essay towards a Real Character and a Philosophical Language*, and to the unpublished, and now lost, Latin revision of the work.¹⁴ Wilkins's *Essay* appeared in 1668, with the approbation and from the printer of the Royal Society. In his preface, Wilkins made 'particular mention' of

that most Learned and Inquisitive Gentleman, a worthy Member of the Royal Society, Mr. Francis Willoughby, who hath made it his particular business, in his late Travails through the most considerable parts of Europe, to inquire after and understand the several species of Animals, and by his own Observations is able to advance that part of Learning, and to add many things, to what hath been formerly done, by the most Learned Authors in this kind.

Only two other contributors were singled out in the same fashion, one of whom was Ray, who had compiled the botanical tables.¹⁵

I shall discuss below Willughby's classification, as it survives in the English version. Willughby continued to revise his classification as he and Ray worked with Wilkins on a Latin version of the work. Although this was never published and seems to have been lost, Willughby seems to have improved on the English version in some respects. Ray had a high regard for the result: some time in the second half of 1678 he wrote to John Aubrey, who apparently had inquired about animal classifications: 'Tables of insects you will scarce meet with better than those Mr. Willughby drew for ye Latine edition of the *R[real] Ch[aracter]*.'¹⁶

Insects were also subjects of letters that Willughby wrote in 1670 and 1671 to *Philosophical Transactions*, on bees and parasitoid wasps.¹⁷ But most of the observations that he gathered remained unpublished at his death in 1672. As we shall see, however, Ray would eventually ensure that many of them saw the light, but only decades later, after Ray's own death.

RAY'S *HISTORIA INSECTORUM*

Ray did eventually take up insect studies in earnest, but much later, starting only in 1690, when his health had already begun to fail. Nonetheless, he worked on insects diligently for the remaining 14 years of his life, with the aim of publishing a history of them: not a history of all insects, whose number he initially estimated at well over 10 000,¹⁸ but only of British insects, and of exotics that were in the London collections of Hans Sloane, James Petiver and a few others.¹⁹ At the beginning, unlike in *Ornithology* and *History of Fishes*, he did not conceive of this enterprise as editing and publishing Willughby's work, although, as we shall see, Willughby ultimately had a large hand in it. The work appeared posthumously, in incomplete form, under the title *Historia insectorum*; for this reason it offers us an opportunity to see the successive layers of its composition, going back to the 1660s, if not before.

The work is composed of four principal parts.

- (i) *Methodus insectorum* [method, i.e. taxonomy, of insects], which Ray composed in 1704 and published in 1705. Part of this work was based on Willughby's classification of insects that did not undergo metamorphosis.
- (ii) A systematic description of insects, more or less but not entirely following the order in *Methodus*. This part also contains a couple of odd insertions: a listing of different dragonflies (which had earlier been described) and a letter from Derham to Ray on gnats.
- (iii) A series of chronologically organized observations of adult butterflies and moths and various caterpillars, performed by Ray in the 1690s.
- (iv) As an appendix, a series of descriptions of British beetles by Martin Lister.

Ray died early in 1705 (New Style). His papers on insects were initially taken by his friend Samuel Dale, who, however, refused Sloane's request that he edit the unfinished work. Instead, the task was undertaken by William Derham, who seems to have done nothing with them initially but then sent them in the summer of 1708 to Sloane at the Royal Society.²⁰ Sloane seems to have been in no rush to have them printed, because in September 1708 Tancred Robinson reported to Martin Lister that 'Mr. Ray's Papers upon insects are given to the Royall Society in order to be printed, at present they lye in Dr. Sloans hands, and when they will see a Resurrection I cannot divine.' Perhaps the question of whether to commission engravings had been vexing Sloane; in July 1709 Robinson wrote, 'H. Aston'²¹ moved at a meeting of the Royal Society that a committee be formed to consider whether the work could be printed as it was, without figures. The decision was positive, and in August 1709 Robinson wrote again to Lister, 'With much Labour we have got at last Mr. Ray's posthumous piece de Insectis (praesertim Britan.) out of Dr. Sloanes hand, which may make about 40 sheets in 4to. Part of it is perfect, the other only Fragments. We hope to get it into the Press out of hand.'²² The printer in fact finished it in 1710.

Despite the work's publication history and eclectic organization, initial responses to it were positive. Both *Journal des Sçavans*, in January 1711, and *Journal de Trévoux*, nearly four years later (December 1714), spoke highly of it.²³ Neither anonymous reviewer seemed to know much about insects, however; they limited themselves to giving a brief overview of the contents and, in the former, a summary of the section on spiders, which the author noted was based on the works of 'MM. Willughbi & Lister'.²⁴ And when they enumerated the different kinds of insect, the reviewers did not distinguish between larvae and adults, including both *chenilles* and *papillons* among the different kinds of insect.

WILLUGHBY'S MISSING MANUSCRIPT

How does this work, partly edited and partly compiled by Ray, organized to an unknown degree by Derham, delayed by Sloane, and then finished by a Royal Society committee, relate to the observations that Francis Willughby made of insects in the 1660s and early 1670s, some four decades earlier? What came from Willughby, and what did Ray add? There is one document that would be of immense help in answering this question, if only it survived: Francis Willughby's manuscript history of insects.

In May 1691 Ray mentioned the manuscript in an offhand fashion, in a letter to Richard Waller, Secretary of the Royal Society: ‘Mr. Willughby’s Observations concerning Insects, which were sometimes in my hands, I have long since delivered up to his son Sir Thomas Willughby, who will I suppose in time take care to publish them.’²⁵ Clearly, at this point Ray was thinking of his own history of insects as an independent project, but his phrasing implies that Willughby’s work was in a relatively finished state.

Over a decade later, however, Ray made inquiries with Sir Thomas about obtaining this manuscript. In April 1703 Ray wrote to both Derham and Sloane, indicating that he hoped soon to procure Willughby’s manuscript and collections.²⁶ Perhaps he had written earlier, but in July of the same year Ray expressed his concern to Sloane about Sir Thomas’s health: he had not received a reply to his earlier request, and he knew that Sloane had treated Willughby.²⁷ By August 1704 Ray had acquired Willughby’s ‘History and Papers’, and was working them into his manuscript.²⁸

Although Ray did not explain this change of heart, we may hypothesize that he initially thought he might surpass Willughby’s observations from the 1660s and early 1670s, which he had not seen for decades. As he sensed his own death approaching, though, he decided to expand his own manuscript by adding Willughby’s material to it. This hypothesis is supported by the cross-references between Willughby’s list of beetles and Ray’s. In the former, Ray often cross-referenced Willughby’s description with his own.²⁹ Such references suggest that had Ray lived to finish the work, he would have combined both descriptions into one complete history of each beetle.

Given that Ray received Willughby’s manuscript only a year or so before his final illness and death, it is striking how much of *Historia insectorum* comes from Willughby. Broadly speaking, one can identify three kinds of contribution from Willughby to the work.

- (i) Descriptions identified with the initials ‘F. W.’ These seem to be transcriptions from (or translations of) Willughby’s manuscript.
- (ii) Insects attributed to ‘D. Willughby.’ These are sometimes of individual species, but also of groupings, such as the first section of beetles, ‘Scarabaei antennis globulosis D. Willughby.’³⁰
- (iii) Mentions of Willughby in descriptions primarily written by Ray or taken from other sources, sometimes long after Willughby’s death, as with the butterfly that Petiver called ‘papilio croceus’ in his museum.³¹

Of course, Willughby’s untimely death meant that many of his observations were in unfinished form, as Ray wrote about the history of spiders.³² That makes it difficult to assess whether the material attributed to Willughby in *Historia insectorum* was transcribed verbatim or not, although occasional interpolations in square brackets suggest that Ray scrupulously distinguished his additions from Willughby’s.

Having sketched out the evidence for Ray’s and Willughby’s interests in insects, and the chief sources we have for evaluating them, I now turn to what those sources reveal about how the two naturalists attended to insects.

CLASSIFYING INSECTS

In his work for Wilkins, Willughby had classified insects according to their mode of generation.³³ His first broad division was into those that, on the one hand, had a

generation ‘analogous to that of other Animals; which breed young like themselves, growing from a lesser to a greater magnitude, not being transmutable into any other *Insects*’, and those that, on the other, had an ‘Anomalous’ generation. These latter, in turn, were divided into two kinds: those that were ‘designed to a further tra[n]smutation’, such as maggots, caterpillars and the like, and those that had gone through such a transmutation, from egg to larva to pupa to adult.³⁴

This classification effectively included each endopterygote insect twice: once in its larval form and once in the adult form.³⁵ It is possible that this was due to Wilkins’s requirements: in the year after *Real Character* was published, Ray complained to Lister that the tables of plants he had done for Wilkins were accommodated to the author’s system, not to nature.³⁶ But perhaps not: in the 1670s Ray, too, thought that Aldrovandi’s classification, which also separated larval and adult forms, was ‘no ill one’.³⁷ Habits of mind that emphasized the individual specimen, observed or collected in a particular moment, would naturally treat the radically different larval and adult forms as distinct creatures.

Beyond those broad divisions, Willughby’s classification of insects in *Real Character* shows his attention to behaviour as well as to generation and morphology. He distinguished locusts and mantises from crickets by their habitats: the former lived in fields and fed on plants, whereas the latter lived in holes in the ground or houses. Sometimes, behaviour was diagnostic: the woodlouse or sow was ‘apt to roul it self up when touched.’³⁸ The inchworm’s movement was diagnostic. So were bees’ honey-making and the act of living gregariously, which led Willughby to put the ant and the gnat together. The death-watch beetle was defined by its sound and by living in houses, as well as by its form.

The most obvious difference between *Real Character* and Ray’s *Methodus insectorum* is that Ray collapsed Willughby’s groups of insects that undergo ‘anomalous’ generation into one, comprising both larval and adult forms. That, in turn, implies that Ray had rethought insect classification between the 1670s and his resumption of insect studies in the 1690s. Jan Swammerdam’s *Historia insectorum generalis*, published in Dutch in 1669 and in French translation in 1682, had a great impact on Ray’s thinking about insect classification. Ray may have read Swammerdam’s book before July 1690, when he proposed dividing insects into ‘those that do not undergo a change, and those that do suffer some kind of metamorphosis.’ However, the latter group was divided according to the number of feet their larvae possessed, which was not a feature of Swammerdam’s classification; that suggests that he had not yet discovered Swammerdam.³⁹

By 1692 Ray had definitely read Swammerdam. He quoted the French translation in the second edition of *The Wisdom of God*, and in a letter that year to Edward Lhwyd he proclaimed that Swammerdam’s *Historia insectorum generalis* was ‘certainly ye best book that ever was written upon that subject.’⁴⁰ He reiterated his praise in later letters to Sloane, Derham and Petiver.⁴¹ As a result of his encounter with Swammerdam, Ray maintained Willughby’s broad division of insects that did not undergo metamorphosis but radically revised the rest of Willughby’s classification. In doing so, however, he retained some of Willughby’s key observations, such as the taxonomy of the caddis flies. Willughby had divided them according to whether their larval cases were fixed or mobile, and then the shape and composition of the cases, and he had noted their double moult from larva to pupa and then to imago.⁴²

Ray’s motivation was in part practical. In 1690, shortly after returning to insects in earnest, Ray remarked to Lhwyd that their species were nearly innumerable. That remark

was a preliminary to Ray's comments in *The Wisdom of God*, in 1691, about the number of insects. There he noted:

The Butterflies and Beetles are such numerous Tribes, that I believe in our own native Country alone the Species of each kind may amount to 150 or more. And if we should make the Caterpillars and Hexapods from whence these come to be distinct Species, as most Naturalists have done, the number will be doubled. But if those be admitted for distinct Species, I see no reason but their Aureliae also may pretend to a Specifick difference from the Caterpillars and Butterflies; and so we shall have 300 Species more, therefore we exclude both these from the degree of Species, making them to be the same Insect under a different larva or Habit.⁴³

However, this difference in classification did not necessarily lead to any differences in observational practice. Ray's observations of lepidopterans in the late 1690s, included in *Historia insectorum*, were done by year and by form: caterpillars, (adult) butterflies and (adult) 'phalaenae' (i.e. moths). Ray used a series of cross-references to relate larval and adult forms, but this was much the same as what Aldrovandi had done a century earlier.⁴⁴ And when Ray described the dead specimens that Petiver, Sloane and others sent from London to Black Notley, he was perforce limited to describing the adult form of the insect. By the 1690s, Ray thought that a complete history of an insect required a diachronic element, with attention to the time, place and manner of metamorphosis, following Swammerdam's method (though Swammerdam himself had little interest in an exhaustive enumeration of species). The individual acts of observation that led to the complete history, though, did not necessarily involve the same diachronic element.

Both Willughby's and Ray's classifications of insects reveal their interest in insects' generation and metamorphosis, their behaviour and their diversity. These three areas were the focus of their attention, to the exclusion of other areas such as internal anatomy (the subject of Malpighi's *De Bombyce*, and of Swammerdam's largely unpublished work of the 1670s).⁴⁵ When the young Willughby and the somewhat older Ray attended to insects in the 1650s and 1660s, all three areas fascinated them. By the time the elderly Ray returned to insects in the 1690s, however, his health, his working methods and his interests led him to focus primarily on diversity, although he would use metamorphosis as an organizing scheme.

INSECT LIFE CYCLES AND METAMORPHOSIS

Ancient, medieval and Renaissance writers on insects recognized that some of them metamorphosed, but they did not consider this a fundamental character of those that did; rather, they treated metamorphosis as the change of one kind of creature into a radically different kind. Ulisse Aldrovandi and Thomas Moffett cross-referenced larval and adult forms, but they did not take the step of combining the two distinct forms into one history. The first significant studies of insect metamorphosis were being done at the time that Willughby and Ray were working together. Johannes Goedaert's *Metamorphosis naturalis* appeared in three parts between 1660 and 1669, in Dutch and Latin translation.⁴⁶ There is no evidence that Willughby was familiar with this work; Ray did not know it as late as 1678.⁴⁷ Malpighi's *De Bombyce*, in contrast, had been published in 1669 in London at the order of the Royal Society, and would surely have been known to Willughby and Ray. But this work emphasized Malpighi's dissections of distinct stages (especially the caterpillar), not the insect's transformation.

Willughby was thus at the forefront of contemporary inquiry in the questions he raised about metamorphosis, despite his separation of larvae and adults in his classification. An intriguing passage in *Historia insectorum* attributed to him suggests that it was a puzzle: of one caterpillar described by Aldrovandi, he noted: 'Some of these turn into chrysalises that produce . . . butterflies Others—in fact, the majority—turn into white fly-like chrysalises, out of which flies emerge Those that turn into butterflies do so more quickly than those that become flies.'⁴⁸

As Willughby continued his research, he probed further into the phenomenon that he came to recognize as insect parasitoidism, considering not only ichneumon wasps, of which he described many varieties and about which he wrote to Oldenburg for *Philosophical Transactions*, but also tachinid flies, which parasitize caterpillars. Ray writes that Swammerdam described them: 'but Swammerdam was not the only one who observed this insect, I mean its larvae. They were seen and described by Mr. Willughby and Mr. Lister, who says much about their origin.'⁴⁹ Other parasites, like the botfly, also attracted Willughby's attention.⁵⁰

Willughby carefully observed the life cycles of many other insects, noting puzzles such as an adult dragonfly that emerged from a larva only half its length.⁵¹ In spite of his interest in metamorphosis, and his awareness that parasitism was common in insect larvae, he accepted that they did sometimes generate spontaneously. In a 1670 letter to Henry Oldenburg, he noted that when bee larvae 'miscarry', the 'corruption of the matter within the cases' produces 'little Hexapods' that give rise to beetles.⁵² The generation and metamorphosis of insects fascinated him, but he did not outright reject traditional views of their origin.

When Ray returned to the study of insects, he, too, paid close attention to their metamorphosis. In particular, he collected caterpillars and reared them in his house at Black Notley to find out what kind of chrysalis and adult they would become. By that time he had the examples of Goedaert and Swammerdam to follow, as well as his friend Lister's experiments on spiders, but Willughby's attempts were an important model for him. Ray sometimes diverged from his friend's judgements: Willughby, for instance, had considered grasshoppers to be non-metamorphosing, on the ground that the larval instars were not that different from the winged adults, whereas Ray, following Swammerdam, placed them in the group of those who metamorphosed without a quiescent pupal stage.⁵³ And having read Redi and Swammerdam, Ray followed them in rejecting 'Æquivocal or Spontaneous Generation.'⁵⁴

INSECT BEHAVIOUR

The two friends also watched how insects behaved. Willughby had an interest in sex that dated back to his Cambridge days.⁵⁵ He continued this after leaving, observing dragonflies' mating 'with curiosity' and describing it in his manuscript history of insects in a way that agreed with what Ray found long afterwards in Swammerdam. He observed two morphologically distinct dragonflies mating and concluded, Ray writes, that the lower one was the female form of the other.⁵⁶ Willughby also observed the behaviour of hornets when they caught bees: after seizing their prey like hawks, they landed and carefully arranged the bee so they could properly pick it up with their feet before returning to their nest.

One early observation was reported both by Willughby in *Philosophical Transactions* and by Ray in *Historia insectorum*. This was the case of a parasitic wasp that had captured a

caterpillar three times its size, which it then dragged more than 15 feet to a hole that it had dug. After clearing the hole, the wasp placed its prey inside, then plugged up the hole and left two pine needles as a marker.⁵⁷ The two descriptions are quite close, but the conclusions differ in a telling way. Ray noted that this behaviour could not come from a creature that was a mere machine, implying that the Cartesians were wrong; it is the only explicit intrusion of his natural theology into *Historia insectorum*. Willughby, meanwhile, said that he and Ray waited a few days, then dug up the caterpillar, which he placed in a box in the hope that it would produce wasps, but it never did. In this case, Willughby was more interested in the sequelae than in the implications for grand natural philosophy, although it is tempting to presume that he and Ray discussed Cartesianism and natural history during their years together in Cambridge or their subsequent travels.

Willughby also experimented with insects, to examine their behaviour more sedulously. To test Moffett's claim that a particular hexapod (beetle grub) ate earthworms, he placed two in a box full of worms. One starved; the other eagerly sucked the worms.⁵⁸ He placed two of another species of hexapod together in a box overnight: one ate the other from the tail to the middle, but the remaining part ran around as if it were unharmed.⁵⁹ A more elaborate experiment involved a pet flea wearing a collar and chain that Willughby bought while travelling with Ray in mainland Europe. Willughby kept it in a box with some wool insulation and fed it daily on his palm, sometimes letting it suck and excrete for hours, until after three months it died of cold.⁶⁰ The point of this experiment is unclear, at least in Ray's telling, but it certainly does reveal Willughby's interest in close, repeated observation—and perhaps a genuine fondness for insects.

For his part, Ray devoted less attention to insect behaviour in his declining years than he and Willughby had given it in the 1650s and 1660s. His comments on metamorphosis draw upon insects raised in captivity, and his examples of insects' striking or unusual actions date from the earlier period. Although undoubtedly due in part to the limitations imposed by Ray's health, in particular his ulcered legs, this neglect was also a consequence of Ray's increasing fascination with the sheer number and diversity of insect species—a fascination that was often mingled with despair at ever finishing his project.

INSECT DIVERSITY

It is striking how many different kinds of insect Willughby and Ray described: not simply in the range of broad groups (Linnaean orders or families) but also, within those groups, the range of species. Moffett's *Theatre of Insects* had described three shield bugs; Aldrovandi's work contained 18 illustrations but the accompanying text merely noted their coloration.⁶¹ Willughby described 26, characterizing them broadly by their habitat (terrestrial or aquatic) and the shape of their body and then, within each group, by size and color.⁶² Willughby named seven species of woodlice. He and Ray described 25 dragonflies. Willughby described spittle bugs, grasshoppers and crickets, the mole cricket, cockroaches, ants, crane flies, beetles, butterflies and moths, as well as creatures considered insects in the period, such as spiders, earthworms and leeches.

From the 1690s Ray, too, described an enormous range of beetles, butterflies, dragonflies and other insects (although not spiders!). He thought he had described every English butterfly (and he was not far off⁶³), but he despaired at ever reaching an end of the different species of moths. And that was far from the end: as he wrote to Lhwyd, in July

1690—therefore only shortly after recommencing his insect studies—Ray commented on the number of butterflies, adding, ‘The Beetle-tribe I hold to be no lesse numerous than they; & the Flyes perchance more. So that I know not but that the species of Insects may be equal to or exceed those of Plants.’⁶⁴ In this he was prescient.

Insect collections were vital to Willughby’s and Ray’s observations of insect diversity. Willughby had a collection, as Ray’s 1703 letters to Derham and Sloane indicate, although we know nothing of its size or range. Ray, too, collected insects as he worked on his history.⁶⁵ His notes on butterflies, reproduced in *Historia insectorum*, contained headings referring to specimens’ locations. Ray kept at least four boxes or cases, identified as ‘P[yxis] M.’ (possibly for *media* or *maxima*), ‘Pyx. rar.’, ‘Pyx. rar. long.’ and ‘Pyxis select.’⁶⁶ Ray noted that some specimens faded with time, one of the drawbacks of working with collections. He also seems to have lost some specimens, recorded in his notes as ‘not in the box’, ‘removed’ or ‘deperdita.’⁶⁷ Such notes suggest that Ray returned to his written records and compared them against specimens to correct his descriptions, just as he did with garden plants and herbarium specimens in his botanical work.

Ray also used other collectors’ specimens. He referred to specimens in ‘Mr. Dales Box’, and beginning in 1692 he organized the transport of specimens from Hans Sloane’s and James Petiver’s collections in London, and Tilleman Bobart’s and Edward Lhwyd’s in Oxford, to Black Notley, where he described them and then sent them back.⁶⁸ At first he was concerned that they would suffer considerable damage from ‘shaking & jolting’ in the wagon, but he was delighted to find that when properly fixed in their boxes they ‘came as entire as they were sent out.’⁶⁹ The collections of these virtuosi allowed Ray to extend the range of his work; they also allowed him to verify that he had already described nearly all the day-flying butterflies of England. However, relying on collections also led Ray, far more than Willughby, to emphasize morphological diversity over metamorphosis and behaviour. Had Ray lived to complete *Historia insectorum*, metamorphosis would have provided the overall structure (as in *Methodus insectorum*), but the individual entries would have been the morphological descriptions of insects, many of them based on dead specimens.

CONCLUSION

Willughby and Ray’s studies of insects reveal how insects had become a significant focus of attention for naturalists in the second half of the seventeenth century. Willughby in particular had a wide-ranging interest in insects for someone educated in the 1650s, with only a handful of works—principally Aristotle, Pliny, Aldrovandi and Moffett—on which to draw. His attention to metamorphosis, behaviour and diversity was striking. The last of these might have been at least in part a consequence of his botanizing with Ray, because botanists had long been interested in distinguishing species, something that Ray thought they had often taken too far.⁷⁰ But his focus on metamorphosis, his sustained attention to it and his recognition of certain problems connected with it was unusual.

As Eric Jorink has recently shown, Goedaert’s investigations into insect generation were the first of their kind. He started them in 1635, but it was only 25 years later that he had decided to publish them, most probably at the insistence of his friend Johannes de Mey, a minister and natural philosopher.⁷¹ Although it would be tempting to see de Mey’s

encouragement as a response to William Harvey's 1650 work on generation, the chapter on insects that de Mey provided for Goedaert's first volume draws on Aldrovandi's 1602 work and makes no mention of Harvey. De Mey accepted the common belief that many, if not all, insects were generated spontaneously from putrefying matter. His notes do mention John Johnston's 1657 insect book, so perhaps that prompted him to press his friend to publish.⁷²

Other investigations into insect generation in the 1660s, including Redi's and Swammerdam's, were clearly responses to the belief in spontaneous generation, prompted by Harvey's argument that all animals came from an egg.⁷³ Further study of Willughby's education may reveal that he, too, was engaging with Harvey's work—or extending it, because Harvey's own notes on insects were stolen during the Civil War, as he lamented in his work.⁷⁴ Regardless of whether Willughby was responding directly to Harvey, he was engaged with a central problem of natural philosophy in his era.

As we have seen, Ray's work from 1690 to his death was more concerned with describing diversity than with metamorphosis or behaviour. This reflects his conviction that Swammerdam had already resolved many of its mysteries, as well as the practical limits of his declining health and his use of the collections of other virtuosi. Ray died with different parts of the work in various stages of completion, and in lieu of the engravings he had hoped to procure by subscription, the volume included only a short note at the end referring readers who wished to see pictures to Merian's publications.⁷⁵

Even in its imperfect form, though, *Historia insectorum* was read carefully by Ray and Willughby's successors; it was cited frequently by Linnaeus, who listed 'Raius' and himself as the best describers of insects.⁷⁶ It is tempting to speculate on what Willughby might have produced had he actually finished and published his manuscript history. It might have combined the careful observations, if not microscopic dissections, of Swammerdam with the taxonomic diversity of the later Linneans. It is hard to say, unless the missing manuscript is discovered. To return to Stearn's parallel with Linnaeus and Artedi: Willughby certainly did more than Artedi, whose name adorns the facade of the library of the Artis zoo in Amsterdam. And at least in insects, he left a profound mark not only on Ray but, through *Historia insectorum*, on later insect studies.

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NOTES

- 1 The works in question are Francis Willughby, *Ornithologiae libri tres: In quibus aves omnes hactenus cognitae in methodum naturis suis convenientem redactae accurate describuntur, descriptiones iconibus elegantissimis & vivarum avium simillimis, aeri incisus illustrantur* (Impensis Joannis Martyn, Londini, 1676); Francis Willughby, *The Ornithology of Francis Willughby* (printed by A. C. for John Martyn, London, 1678); Francis Willughby, *De historia piscium libri quatuor* (E Theatro Sheldoniano, Oxonii, 1686); John Ray, *Historia*

- insectorum: . . . opus posthumum jussu Regia Societatis Londinensis editum; cui subjungitur appendix De scarabais Britannicis, autore M. Lister (Impensis A. & J. Churchill, Londini, 1710).*
- 2 Charles E. Raven, *John Ray, naturalist: his life and works*, 2nd edn (Cambridge University Press, 1950), pp. 308 and 336.
- 3 William T. Stearn, 'The Wilkins Lecture 1985: John Wilkins, John Ray and Carl Linnaeus', *Notes Rec. R. Soc. Lond.* **40**, 101–123 (1986), at pp. 116 and 119.
- 4 On the study of insects in early modern Europe, see the texts excerpted and summarized in F. S. Bodenheimer, *Materialien zur Geschichte der Entomologie bis Linné* (W. Junk, Berlin, 1928), as well as recent studies by Yves Cambefort, 'Artistes, médecins et curieux aux origines de l'entomologie moderne (1450–1650)', *Bull. Hist. Épistémol. Sci. Vie* **11**, 3–29 (2004), Eric Jorink, *Het Boeck der Natuere: Nederlandse geleerden en de wonderen van Gods schepping, 1575–1715* (Primavera Pers, Leiden, 2006)/Eric Jorink, *Reading the Book of Nature in the Dutch Golden Age, 1575–1715* (Brill, Leiden, 2010), Brian W. Ogilvie, 'Nature's Bible: insects in seventeenth-century European art and science', *Tidsskr. Kulturforsk.* **7**, 5–21 (2008), Domenico Bertoloni Meli, 'The representation of insects in the seventeenth century: a comparative approach', *Ann. Sci.* **67**, 405–429 (2010), and Janice Neri, *The insect and the image* (University of Minnesota Press, Minneapolis, 2011).
- 5 Richard Serjeantson, paper presented at the Willughby project meeting, Hassop Hall, Derbyshire, 25 April 2012. On Willughby's life more generally, see the biography in Francis Willughby, *Francis Willughby's book of games: a seventeenth-century treatise on sports, games, and pastimes* (Ashgate, Aldershot, 2003).
- 6 John Ray, *Observations topographical, moral, & physiological made in a journey through part of the low-countries, Germany, Italy, and France with a catalogue of plants not native of England, found spontaneously growing in those parts, and their virtues* (printed for John Martyn, London, 1673), Preface, sig. [A6]r.
- 7 John Ray, *Further correspondence of John Ray* (printed for the Ray Society, London, 1928), p. 69.
- 8 Anna Marie Roos, personal communication, 25 April 2012.
- 9 Willughby, *Ornithology* (*op. cit.* (note 1)), sig. A3r–v.
- 10 John Ray, *The correspondence of John Ray: Consisting of selections from the Philosophical Letters published by Dr. Derham, and original letters of John Ray, in the collection of the British Museum* (printed for the Ray Society, London, 1848), pp. 29–30.
- 11 John Ray, *Catalogus plantarum circa Cantabrigiam nascentium: In quo exhibentur quotquot hactenus inventae sunt, quae vel sponte proveniunt, vel in agris seruntur; una cum synonymis selectoribus, locis natalibus & observationibus quibusdam oppido raris. Adjiciuntur in gratiam tyronum, index Anglo-latinus, index locorum, etymologia nominum, & explicatio quorundam terminorum* (apud Jo. Martin, Ja. Allestry, Tho. Dicas, ad insigne Campanae in coemeterio D. Pauli, Londini, 1660), unpaginated preface, pp. 134–138.
- 12 Francis Willughby, 'Account of the reproduction of insects given by Francis Willughby', Royal Society archives, Cl.P./15i/2. I should like to thank an anonymous reviewer for bringing to my attention this manuscript, which I have not had the opportunity to consult.
- 13 Ray to Derham, 16 August 1704, in Ray, *op. cit.* (note 10), p. 452. In *Correspondence*, Edwin Lankester identified the addressee as Sir Hans Sloane, but that cannot be correct: Ray refers to the author's recent publication on the death-watch beetle in *Philosophical Transactions*; Derham's letter on that subject appeared in vol. 24, pp. 1586–1594 (1704).
- 14 On Wilkins's *Essay* and its context, see Mary M. Slaughter, *Universal languages and scientific taxonomy in the seventeenth century* (Cambridge University Press, 1982); Sidonie Clauss, 'John Wilkins' *Essay* toward a Real Character: its place in the seventeenth-century episteme', *J. Hist. Ideas* **43**, 531–553 (1982); Umberto Eco, *The search for the perfect language* (Blackwell, Oxford, 1995); R. Lewis, 'The publication of John Wilkins's 'Essay' (1668): some contextual considerations', *Notes Rec. R. Soc. Lond.* **56**, 133–146 (2002).

- 15 John Wilkins, *An essay towards a real character and a philosophical language* (printed for Sa: Gellibrand, and for John Martyn printer to the Royal Society, London, 1668), unpaginated preface.
- 16 Ray, *op. cit.* (note 7), p. 165.
- 17 Francis Willughby, 'Extracts of Two Letters, Written by Francis Willughby Esquire, to the Publisher, from Astrop, August 19th and from Middleton, Sept. 2d. 1670 Containing His Observations on the Insects and Cartrages, Described in the Precedent Accompt', *Phil. Trans. R. Soc. Lond.* **5**, 2100–2102 (1670); Francis Willughby, 'Another Extract of a Letter Written from Middleton in Warwickshire to the Publisher July 10th. by Francis Willughby Esquire; About the Hatching of a Kind of Bee, Lodged in Old Willows', *Phil. Trans. R. Soc. Lond.* **6**, 2221 (1671); Francis Willughby, 'A Letter of Francis Willughby Esquire, of August 24, 1671, Containing Some Considerable Observations about That Kind of Wasps, Call'd Vespa Ichneumon; Especially Their Several Ways of Breeding, and among Them, That Odd Way of Laying Their Eggs in the Bodies of Caterpillars, &c', *Phil. Trans. R. Soc. Lond.* **6**, 2279–2281 (1671).
- 18 John Ray, *The Wisdom of God manifested in the works of the creation* (printed for Samuel Smith, at the Princes Arms in St. Pauls Church-Yard, London, 1691), pp. 5–7. In the second edition (1692) he doubled that estimate.
- 19 Ray, *op. cit.* (note 10), pp. 410–411, 414–415, 417–418, 430 and 432–433.
- 20 Raven, *op. cit.* (note 2), p. 403.
- 21 Possibly an error for Francis Aston; there was no 'H. Aston' among the early Fellows of the Royal Society.
- 22 Ray, *op. cit.* (note 7), pp. 309–310.
- 23 *Journal des Sçavans, Pour le Mois de Janvier 1711* (Chez les Janssons à Waesberge, Amsterdam, 1711), pp. 29–36; *Mémoires pour l'histoire des sciences et des beaux-arts, Recueillis par ordre de son Altesse Serenissime Monseigneur Prince Souverain de Dombes* (De l'imprimerie de S.A.S., Trévoux, Décembre 1714), pp. 2128–2129.
- 24 *Journal des Sçavans*, p. 31 (January 1711).
- 25 Ray, *op. cit.* (note 7), pp. 98–100.
- 26 Ray, *op. cit.* (note 10), pp. 414–417.
- 27 *Ibid.*, pp. 430–431.
- 28 *Ibid.*, pp. 448–449 and 452.
- 29 Ray, *op. cit.* (note 1), pp. 89ff.
- 30 *Ibid.*, pp. 89–90.
- 31 *Ibid.*, pp. 112–113.
- 32 *Ibid.*, p. 11.
- 33 I address how this classification fits into the history of insect classification *ca.* 1550–1750 in 'Order of insects', manuscript under consideration at *Annals of Science*.
- 34 Wilkins, *op. cit.* (note 15), p. 122.
- 35 In modern entomology, endopterygotes are insects that undergo holometabolous development, or complete metamorphosis.
- 36 Ray, *op. cit.* (note 10), p. 30.
- 37 Ray, *op. cit.* (note 7), p. 165.
- 38 Wilkins, *op. cit.* (note 15), p. 124.
- 39 Ray, *op. cit.* (note 7), pp. 208–209.
- 40 John Ray, *The Wisdom of God manifested in the works of the creation*, 2nd edn (printed for Samuel Smith, at the Princes Arms in St. Paul's Church-yard, London, 1692), part 2, pp. 75–76 (mentioned by Raven, *op. cit.* (note 2), p. 392); Ray, *op. cit.* (note 7), pp. 226–228.
- 41 Ray, *op. cit.* (note 10), pp. 363–364, 399–400, 410–411 and 434–435.
- 42 Ray, *op. cit.* (note 1), pp. xii–xiii and xv.

- 43 Ray, *op. cit.* (note 18), p. 6.
- 44 On Aldrovandi, see Ogilvie, *op. cit.* (note 4), p. 9.
- 45 Posthumously published by Herman Boerhaave in Jan Swammerdam, *Bybel der natuure of Historie der insecten tot zekere soorten gebracht* (by I. Severinus, Leyden, 1737).
- 46 Johannes Goedaert, *Metamorphosis naturalis, ofte Historische beschryvinghe vanden oirspronk, aerd, eggenschappen ende vreemde veranderinghen der wormen, rupsen, maeden, vliegen, witjens, byen, motten ende dierghelijcke dierkens meer* (3 volumes) (Jaques Fierens, Boeck-verkooper, inde Globe, Middelburgh, [1660–69]). The date of the first volume is often given as 1662, but see Ella Reitsma, *Maria Sibylla Merian and daughters: women of art and science* (The Rembrandt House Museum, Amsterdam; J. Paul Getty Museum, Los Angeles, CA; Waanders Publishers, Zwolle, 2008), p. 68, n. 22. Christiaan Huygens possessed a copy in November 1660: Christiaan Huygens, *Œuvres complètes* (M. Nijhoff, The Hague, 1888–1950), vol. 22, p. 535 (I should like to thank an anonymous reviewer for bringing this passage in Huygens’s travel diary to my attention).
- 47 Ray to Lister, 19 April 1668, in Ray, *op. cit.* (note 10), p. 24.
- 48 Ray, *op. cit.* (note 1), p. 341.
- 49 *Ibid.*, p. xv; see Willughby, ‘Observations about *Vespae Ichneumones*’; on tachinids, Ray, *op. cit.* (note 1), p. xiv.
- 50 *Ibid.*, p. xiv.
- 51 *Ibid.*, pp. vii, 48 and 51.
- 52 Willughby to Oldenburg, 2 September 1670, in *The correspondence of Henry Oldenburg* (University of Wisconsin Press, Madison (imprint varies), 1965–86), vol. 7, p. 150.
- 53 Ray, *op. cit.* (note 1), p. viii.
- 54 Ray, *op. cit.* (note 18), p. 221.
- 55 Serjeantson, paper presented at Hassop Hall, April 2012.
- 56 Ray, *op. cit.* (note 1), p. 48.
- 57 Willughby, ‘Observations about *Vespae Ichneumones*’; Ray, *op. cit.* (note 1), p. 254. Dr Mark Jervis of Cardiff University has informed me that the behaviour suggests a species of *Ammophila* wasp: personal communication, 27 April 2012.
- 58 Ray, *op. cit.* (note 1), p. 5.
- 59 *Ibid.*, p. 6.
- 60 *Ibid.*, pp. 7–8.
- 61 Thomas Moffett, *Insectorum sive minimorum animalium theatrum: Olim ab Edoardo Wottono, Conrado Gesnero, Thomaque Pennio inchoatum: tandem Tho. Moufeti Londinatis opera sumptibusq; maximis concinnatum, auctum, perfectum* (ex officina typographica Thom. Cotes, et venales extant apud Guiliel. Hope, Londini, 1634), p. 174; Ulisse Aldrovandi, *De animalibus insectis libri septem*... (apud Ioan. Bapt. Bellagambam, Bonon, 1602), p. 541.
- 62 Ray, *op. cit.* (note 1), pp. viii and 53–57; the classification on p. 8 gives the number as 23, but there are 26 descriptions of ‘cimices’ or ‘muscae cimiciformes’ in the text.
- 63 Raven, *op. cit.* (note 2), p. 416.
- 64 Ray, *op. cit.* (note 7), pp. 208–209.
- 65 Ray, *op. cit.* (note 10), pp. 363–364.
- 66 Ray, *op. cit.* (note 1), pp. 171, 191, 208, 225 and 233.
- 67 *Ibid.*, pp. 170, 171 and 208.
- 68 *Ibid.*, p. 223; Ray, *op. cit.* (note 10), pp. 416–417, 430, 432–433, 434–435, 443–444 and 453–454.
- 69 Ray, *op. cit.* (note 7), pp. 227, 228, 232–233 and 234.
- 70 See Ray’s comments on Caspar Bauhin in Ray, *op. cit.* (note 18), pp. 7–8.
- 71 Jorink, *Reading the book of nature* (*op. cit.* (note 4)), pp. 202–207.

- 72 Goedaert, (*op. cit.* (note 46)), vol. 1, unpaginated chapter, sig. (c)3r–[(c)8]v; Johnston is first mentioned on p. 22, note d.
- 73 See Matthew Cobb, *Generation: the seventeenth-century scientists who unraveled the secrets of sex, life, and growth* (Bloomsbury USA, New York, 2006).
- 74 William Harvey, *Exercitationes de generatione animalium quibus accedunt quaedam de partu, de membranis ac humoribus uteri & de conceptione* (Typis Du-Gardianis; impensis Octaviani Pulleyn, Londini, 1651), sig. a2v, p. 229; Cobb, (*op. cit.* (note 73)), pp. 23–24.
- 75 Ray, *op. cit.* (note 10), pp. 448–449 and 453–454; Ray, *op. cit.* (note 1), p. 398.
- 76 Carolus Linnaeus, *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum charateribus, differentiis, synonymis, locis*, 10th edn (Impensis L. Salvii, Holmiae, 1758), p. 341.