Nature's Bible: Insects in Seventeenth-Century European Art and Science

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Abstract
Artists and naturalists in seventeenth-century Europe avidly pursued the study of insects. Since entomology had not yet become a distinct discipline, these studies were pursued within the framework of natural history, miniature painting, medicine, and anatomy. In the late sixteenth century the Renaissance naturalist Ulisse Aldrovandi collected and described individual insects and their lore but showed little sustained interest in their temporal transmutations; meanwhile, the court artist Joris Hoefnagel studied the structure of insects in order to paint real and imaginary insects while giving them an emblematic interpretation. By the middle of the seventeenth century the painter Johannes Goedaert was assiduously studying insect transformations, which he saw as evidence of God's wondrous works. His work was critiqued and systematized by the physicians Martin Lister and Jan Swammerdam, who insisted that orderly transformation was the best sign of God's handiwork. These examples show how verbal descriptions and illustrations of insects easily crossed disciplinary boundaries; knowledge generated in one particular context moved into others where it was critiqued but also employed in new investigations.

Keywords:
Natural history, art, Science, insects, entomology

The Bible of Nature; or, The History of Insects Brought into Certain Classes, is the strange title that Jan Swammerdam (d. 1680) gave to his posthumously published *magnum opus* (Swammerdam 1737-38). The strangeness lies in the contrast between the subtitle's sober promise of order and the expansive, if not temerarious, claims of the title. But Swammerdam's title is strangely appropriate for the study of insects in the seventeenth century. Characterized by scholarly erudition, painstaking observation, and artistic flair, the study of insects reveals, in miniature, many cultural and intellectual interests of the century and how knowledge circulated between distinct yet permeable contexts. As we shall see, it also made eminent sense to Swammerdam;

it expressed his sense of the relationship between rational order and divine creation.

Like natural history in general, the study of insects was avidly pursued in the late Renaissance and after. The first European natural history of insects, Ulisse Aldrovandi's 1602 *De animalibus insectis*, was the fruit of a lifetime of collecting insects and insect-lore. Other sixteenth-century naturalists had collected material on insects – for instance, Edward Wotton, Conrad Gessner, and Thomas Penny, whose notes were organized for publication by Thomas Moffett and finally published by Theodore de Mayerne (Moffett 1634). But compared with the flood of Renaissance works on plants, quadrupeds, birds, and fishes, insects were little studied (Pinon 1995; Ogilvie 2006). Over the course of the seventeenth century, more and more scholars turned to the study of insects. Though their numbers remained small when compared with eighteenth-century entomologists, they included major figures: for example, Marcello Malpighi, Antony van Leeuwenhoek, Robert Hooke, John Ray, and Swammerdam. The newly invented microscope offered enhanced possibilities of observation, and insects could cast new light on problems in anatomy and generation (Bodenheimer 1928:vol. 1:325-407; Wilson 1995; Ruestow 1996; Freedberg 2002; Cobb 2006).

Artists, and miniaturists in particular, had long included insects among decorative motifs. But toward the end of the sixteenth century, the so-called Dürer Revival generated new interest in a meticulous depiction of plants, animals, insects, and other natural objects (Koreny 1988; Neri 2003:23). Georg Hoefnagel stunned the court of Rudolf II with his delicate insect replicas and fantasies, and insects came to be familiar parts of Netherlandish still life and vanity paintings (Vignau-Wilberg 1994; Albus 2000). In the second half of the century, the artists Johannes Goedaert and Maria Sibylla Merian consciously set out to use their artistic and observational talents to serve "investigators of nature," denying any fundamental distinction between naturalists and artists.

It would be misleading to call these studies "entomology." That word was coined in 1745 by Charles Bonnet – who rejected it, as too cacophonous – in his *Traité d'insectologie* (his preferred term). It entered English in 1766 (TLF; OED). A discipline may exist before it is named, but the act of naming is often a mark of self-recognition by its practitioners that something new has come into being (see Kelley 1997). Histories of entomology have been written that start in ancient Mesopotamia, but they should really be considered histories of the study of insects – that is, of a scientific object – rather than histories of a discipline (e.g. Bodenheimer 1928, Essig 1936). By using the anachronistic term entomology, they distract the historian's attention from the processes that led to the formation of a new discipline (cf. Rossi 1984:vii). (Of course, "science" is itself a problematic term, especially before 1800: see Pickstone 2007.)

In this essay I offer a series of observations on how and why insects were studied *before* entomology, from the late sixteenth to the late seventeenth century. I offer an essay, not a systematic overview of insect studies; as a result, I must omit a discussion of many artists and scholars who would be considered in a longer study – for instance, the *Melissographia* and other works of the Accademia dei Lincei or the later seventeenth-century works of Marcello Malpighi or Francesco Redi. My focus will be on the different contexts in which insects were

studied and how knowledge changed as it moved from one context to another. In its attention to the role of insect illustrations, this essay is in part a contribution to what Monika Dommann, following W.J.T. Mitchell, has called a "pictorial turn" in the history of science (Dommann 2004). At the same time, I explores the shifting relationship between natural knowledge of insects, moral lessons to be drawn from them, and secular theology (on secular theology see Funkenstein 1986). In joining these themes, insects are for the historian truly wondrous.

Ulisse Aldrovandi: the encyclopedic observer

The hallmark of Renaissance natural history was the careful description of the natural world. Ulisse Aldrovandi's *De animalibus insectis libri VII*, one of the handful of works that Aldrovandi actually published toward the end of his long life as a naturalist and collector, reveals the descriptive impulse at work. At the same time, it reveals how, for Aldrovandi, description was only part of the naturalist's work; the history of insects embraced their meaning, not simply their objective nature.

Insects were a particular problem for naturalists because they were small and practically innumerable. But Aldrovandi was not daunted. Accompanied by an amanuensis and a painter, he prowled the "suburbs" of Bologna, interrogating peasants, having them bring him insects, flying creatures, and reptiles, and studying them. The painter illustrated anything worthy of being painted, while the amanuensis noted down what Aldrovandi considered important; in this way "I was able to assemble a diverse collection (*variam supellectilem*) of insects" (Aldrovandi 1602:sig. †3r). This collection and Aldrovandi's indefatigable reading provided the basis for *De insectis* (on Aldrovandi's collection see Findlen 1994:30).

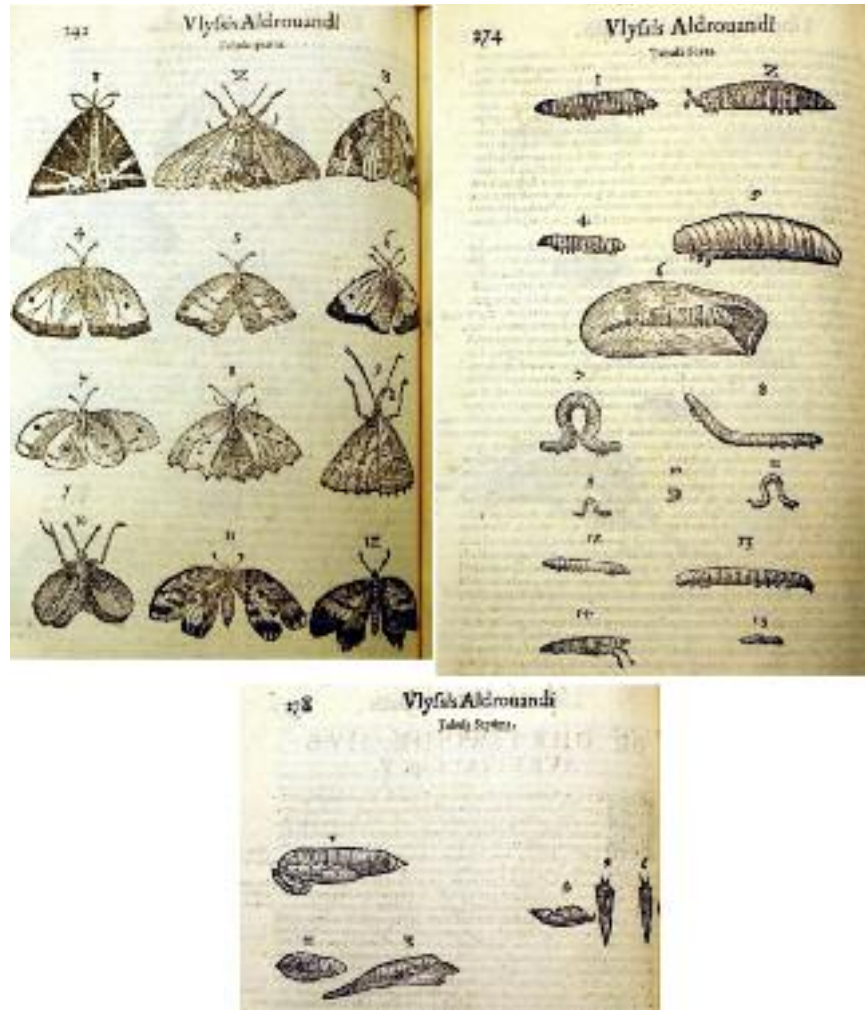

Figure 1.
In his woodcut illustrations, Ulisse Aldrovandi presented each major phase of the butterfly's life cycle synchronically, as if he had laid out specimens in a cabinet. Source: Ulisse Aldrovandi, De animalibus insectis (1602), courtesy of the Entomology, Fisheries & Wildlife Library, University of Minnesota; photo by the author.

Despite the weight of erudition in his work, Aldrovandi was an acute observer (Bodenheimer 1928:vol. 1:247-276). And he had a lot of description to do: his ancient and medieval predecessors had largely neglected to describe insects. For instance, "although there are many kinds of butterflies, I have found none described by the ancients" (Aldrovandi 1602:236). To remedy this lack, Aldrovandi used words and pictures. His chapters on butterflies

(including moths) involved eleven full-page woodcuts, each containing several different species. They were accompanied by morphological descriptions and occasionally by notes on their generation or behavior, though most of that information came later under more general headings like *generatio* and *mores*. Aldrovandi placed great value on illustrations as a source of knowledge. Illustrations showed naturalists distant species; they allowed for communication with contemporaries and posterity in a way that was much more precise than words alone. In a rather naive fashion, Aldrovandi conceived of the artist's task as imitating nature, a conception that, as Giuseppe Olmi has underscored, made the artist a manual laborer who needed a naturalist's direction (1992:24-27).

To understand how Aldrovandi organized the knowledge he generated in pictures and notes, let us take the example of butterflies. The woodcuts in the chapter on butterflies (book 2, chapter 1) included only the imagines (adult forms) of the insects. Aldrovandi discussed the larval form (the caterpillar) three chapters later. Again, he provided several pages of woodcuts, each illustrating several different kinds of caterpillar, along with short morphological descriptions in the accompanying text. The nymphal forms, in turn, received their own chapter, "De chrysalide sive aurelia," with only one woodcut showing a handful of chrysalises.

In brief, Aldrovandi's woodcuts and verbal descriptions aimed to show what a perceptive observer would see when confronted with the individual specimen. What they would not convey, systematically, was how specimens were related: what would come out of the chrysalis that the caterpillar would weave, or where that butterfly had come from and whether its presence signified not only present beauty but also, with the next generation of caterpillars, future devastation. Aldrovandi occasionally noted which butterflies develop from which insects: for instance, "When I had nourished the first caterpillar of the first table for some time in my house, it did not weave a web or sack, but rather formed a chrysalis which gave birth to a darkish yellow butterfly, namely the third in the first table." But he did not do so systematically, though he followed Aristotle in noting that butterflies tend to have the same color as the caterpillars from which they develop (267).

Aldrovandi divided imagines from larvae for several reasons. His classification divided insects into aquatic and terrestrial, the latter into those without feet and those with feet, the latter into those with wings and those without. Among winged, footed, terrestrial insects, we find the butterfly. Among wingless, footed, terrestrial insects, we find the caterpillar (Aldrovandi 1602:sig. †4r). In the body of the book, the two are separated by vast gulfs of Aldrovandian prose. Butterflies get the place of honor after bees and their relatives, in book 2, "Other four-winged insects without wing-cases." Caterpillars are in the same book, but three chapters later. The fact that Aldrovandi placed caterpillars in the book of four-winged insects without elytrae, rather than among the footed, wingless insects (where the table said they should be), shows that he considered them to be related. But his emphasis on synchronic, descriptive morphology led him to play down what he had carefully learned (or in some cases, he admitted, carelessly observed) of their generation and growth.

Contemporary theories of generation encouraged this division. In a tradition going back to Aristotle, larvae, lumped

together as "worms," were generally considered to be imperfect animals that were generated spontaneously. At their death, they formed an egg – the pupa – that then gave birth to a completely new creature, the adult insect (Cobb 2006). Aldrovandi rejected part of this story: his observations had convinced him that butterflies laid eggs that became, in turn, caterpillars, though he left the final determination to the reader (1602:253-256). Nonetheless, he treated caterpillar, chrysalis, and imago as distinct creatures that happened to produce one another. Aldrovandi had practical objections too: Not every caterpillar becomes a butterfly: some die, wrote Aldrovandi, while others form a chrysalis that produces not a winged insect but several worms. And not every butterfly comes from a caterpillar; some come from worms (254-255).

Nonetheless, one page in Aldrovandi's paper collection suggests that he had a nascent interest in studying diachronic development (Aldrovandi 2005:Tavole vol. 007 Animali, fol. 16). This is no simple page from a field notebook. The second row shows a caterpillar, a cluster of eggs, a small larval form, two views of a pupal case, and an adult insect. This page may have been originally intended as part of a systematic study of insect life-cycles: its original layout may have been as follows:

caterpillar		
caterpillar and eggs	pupa	imago (moth)
caterpillar		imago (moth)
		imago (moth)
		imago (moth)

If this is the case, the small larva in the center and the cicadas on the lower left were added later to fill up empty space. Aldrovandi might have intended to fill in the blanks by systematic study: that is, identifying the pupa and imago of the first caterpillar and identifying the caterpillar and pup

But if Aldrovandi intended a systematic study of insect life cycles, as vol. 7, 2, fol. 16 implies – a conclusion that Janice Neri has also reached, independently (2003: 53) – he did not carry it out. Other pages in his notebooks include occasional notes on the relationship between different phases of an insect's life-cycle, but nothing so systematic (Aldrovandi 2005). And they rarely contain much if any information about where an insect would be found or what it ate; though Aldrovandi occasionally noted such associations in his published text, they were not a systematic concern of his.

The meaning of insects, on the other hand, occupied an important place in Aldrovandi's history. His chapter on bees included their mystical, hieroglyphical, moral, symbolic, and emblematic meanings – among other antiquarian lore (Aldrovandi 1602:90-105). Like Conrad Gessner and other Renaissance zoological encyclopedists, Aldrovandi considered such lore to pertain to the history of insects; while Gessner implied that "philology" was an optional part of natural history, Aldrovandi made no such distinction (Harms 1989; Ashworth 1990; cf. Ogilvie 2005). However, he did not insist on any one meaning of insects; rather, he collected them just as he collected descriptions. In his preface to the reader Aldrovandi underscored that insects might exhort us to hard work and prudent action, but he did not systematically develop the moral or ethical implications of insects (Aldrovandi 1602:sig. †3r).

Artists and insects from Joris Hoefnagel to Johannes Goedaert

The northern artistic tradition of trompe-l'oeil miniatures of *naturalia* is another moment in the history of insect study. This tradition appears to have close connections to pilgrimage books and manuscript illumination; its origins have nothing to do with natural history, itself a new discipline in the sixteenth century (Kaufmann and Kaufmann 1993). By the fifteenth century, insects were a common feature of such illustrations, often associated with plants – a colorful combination (Ruestow 1996:48-52). But those associations were not necessarily ecological: that is, specific insects were not associated with the plants on which their larvae or imagines lived and fed.

Janice Neri has shown that these artists were led to insects in large part by Dürer's example. In the context of the "Dürer revival" of the late sixteenth century, the Stag Beetle was both a model and a challenge to Hoefnagel and others. In his manuscript collection *Ignis* (c. 1575-82), Hoefnagel copied Dürer's drawing and then improved it, adding connections between the parts, correcting details, even improving the shadow. He probably used a specimen along with Dürer's drawing. "For Hoefnagel and other artists of the Dürer Renaissance, the motivation for studying nature stemmed in part from the desire to produce flawless imitations of Dürer's images. In this context, the artist's knowledge and mastery of nature progressed in tandem with his knowledge and mastery of image-making practices" (Neri 2003:24-30) In the *Mira calligraphiae monumenta*, on the other hand, Hoefnagel depicted some real insects, but most were imaginary constructs (Bocksay and Hoefnagel 1992; Neri 2003:34-35).

Hoefnagel's approach to insects suggests why Aldrovandi thought his artists needed to be carefully supervised. By studying insects' external form carefully, Hoefnagel learned, as it were, their vocabulary and grammar: that is, the detailed structure of their individual parts and the way those parts were combined to make a complete insect. He could then recombine parts, thereby creating new forms that had never existed – except, perhaps, in the mind of God. In *Ignis*, he associated insects with fire; with rational animals (i.e., man), and with God, the invisible creator of the visible world (Hendrix 1995:376-377). In both *Ignis* and the engravings that his son Jacob prepared from his drawings in 1592, Hoefnagel drew creatively upon the Renaissance emblematic tradition that Aldrovandi had simply summarized (Vignau-Wilberg 1994; see Cambefort 2006).

To contemporaries, the Hoefnagels' work would not have looked like natural history. Unlike Aldrovandi, who employed artists as part of a project to catalogue and describe nature, its practitioners were not naturalists and saw representation of the individual, real or fantastic, as an end in itself, a means for producing beauty and displaying the artist's skill. Naturalists would have seen their work as useful – though they would have severely criticized Joris for depicting chimerical insects that did not really exist. However, artists and naturalists were working closely together in the late sixteenth and early seventeenth century. Current research on Giuseppe Arcimboldo, court painter to Emperor Rudolf II, has uncovered increasing evidence that Arcimboldo corresponded regularly with Aldrovandi and other naturalists and saw himself as engaged, like them, in the project of cataloguing and describing

nature (Kaufmann 2007). Moreover, Joris Hoefnagel's son Jacob studied the life cycle of insects and discussed them with the Dutch naturalist Outgaert Cluyt (Ruestow 1996:52-53). The same connection is found in the works of Johannes Goedaert.

A painter and engraver by profession, Johannes Goedaert (1617-1668) spent his whole life in the town of Middelburg, in the Netherlands. Like many Dutch port cities, Middelburg had a lively community of amateurs interested in collecting and displaying flowers, shells, and other *naturalia* (Goldgar 2007:22-23). Goedaert was literate in Dutch but probably knew no Latin (Van der Pas 1970). His passion was raising insects from larvae caught in the field, which he fed and observed as they underwent their "strange transformations" (Goedaert 1662-69:vol. 1:sig. a8v). His book *Metamorphosis naturalis* (3 parts, 1662-1669), written in Dutch, had the good fortune to be published when naturalists not only said that they wanted first-hand observations stripped of citations and quotations from authoritative predecessors, but had begun to mean it. Goedaert's careful observations ensured him a pan-European reception: the work was translated into Latin (1662-1669), English (1682, from the Latin edition), and French (1700) (Van der Pas 1970:440).

Goedaert's method was simple. He caught larvae ("worms") and brought them home, where he placed them in glass containers. As his interests became known, his neighbors would bring him caterpillars; as his reputation grew, he received material from farther afield, even as far as Paris. He fed them, sometimes on the plant where he had found them, sometimes by offering them different kinds of leaves until he found one they liked. He drew them as larvae, noted when they changed, drew their pupae, noted how long they remained in pupal form and when they emerged, and drew what emerged (imago or parasite). His notes occasionally remarked on the insect's form, but they were mostly on its behavior and metamorphosis.

As with Aldrovandi, illustration was essential to Goedaert's work. His publications consisted of engraved plates keyed to short textual notes, a form that allowed Martin Lister to cut and paste the work together in a completely new order, with re-engraved plates reflecting the new organization. (On Lister's collaboration with artists, see Unwin 1995). Unlike the Dutch miniaturist tradition, Goedaert's plates represented the insect itself in its different phases. In a complete history this involved three stages: the larva, the pupa, and what emerged from the pupa. Occasionally Goedaert depicted the leaf on which the adult laid its eggs or which the caterpillar ate. With his naive eye and "excellent pen-

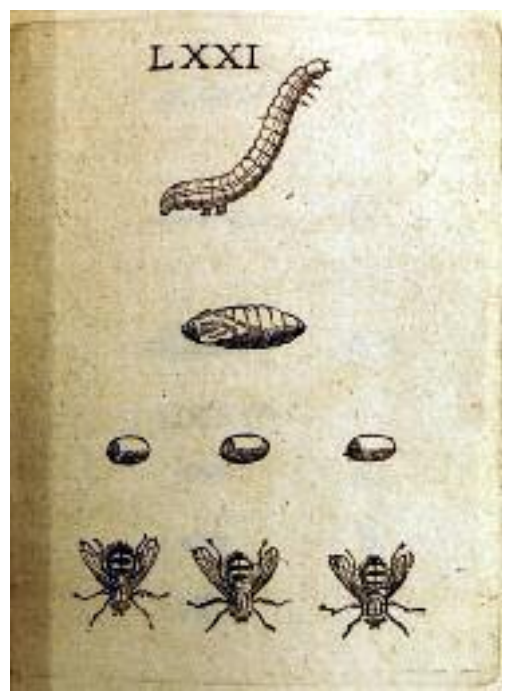

Figure 2.
Read from top to bottom, this engraving by Johannes Goedaert shows the successive stages that Goedaert observed: caterpillar, pupa, and three small eggs that produced flies, the result of parasitism. Source: Johannes Goedaert, Metamorphosis naturalis, part 1 (1662), courtesy of the Entomology, Fisheries & Wildlife Library, University of Minnesota; photo by the author.

cill" (the phrase is Lister's: Goedaert 1682:37), Goedaert depicted form without context: not surprisingly, for he observed his captives in their glass cells, occasionally lamenting their untimely death by starvation when he could not figure out what to feed them. This approach doubtless contributed to the sympathetic reception he found among naturalists like Lister, for his depictions combined his acute observation, the finesse of copperplate engraving, and – for the first time – studies of insects that emphasized their metamorphosis rather than relegating it to the second rank. There are a few precursors to Goedaert's approach in some of Aldrovandi's and Moffett's woodcuts, and as we have seen in Aldrovandi's manuscript illustrations, but none who so single-mindedly, for a period of several decades, observed, drew, and noted the life-cycle of insects.

Goedaert's illustrations, unlike those of Aldrovandi, Moffett, or the miniature tradition, have an irreducible diachronic element. Each engraving has a sequence, usually from larva at the bottom to imago at the top. The figures appear to be drawn at the same scale, so that the relative size of larva, pupa, and imago can be identified, though the text is silent about scale. Because the figures appear alone, against a neutral background, their diachronic relationship is implicit, not explicit. From a descriptive standpoint, the engravings merely denote that the insects depicted belong together; the reader must turn to the notes to figure out the exact nature of their relationship.

Goedaert insisted on this diachronic element because his illustrations were means of capturing his experience as an observer. He drew a caterpillar and waited. He drew its pupa and waited. Then he drew the animal that emerged from it. Sometimes it was a butterfly. Sometimes it was a fly. Sometimes it was another "worm," or several of them. When Goedaert did not know what to feed the adult, or when it refused nourishment, it ultimately starved, though sometimes he released the adults before they reached that point. Only rarely did he illustrate an adult form by itself: for instance, one particularly magnificent butterfly captured in the Parisian Jardin du Roy and sent to him via the Dutch ambassador to Versailles (Goedaert 1682:37-38). Even in this case, though, Goedaert had hoped to find the "origin" of the butterfly in its caterpillar; the illustration was intended to be part of a series, just as the blank spaces in Aldrovandi's manuscript page were intended to be filled in. Indeed, Godaert was sent the butterfly in hopes that he would find the origin: that, and the translations of his work into Latin that followed quickly on its publication in Dutch, suggest the degree of interest in insect metamorphosis in the late seventeenth century. Leibniz even thought that Goedaert's and Jan Swammerdam's insects should be part of a public curiosity cabinet (Wiener 1940:237).

It also suggests the continuing permeability of the natural history community, at least in matters related to insects, and its interest in circulating knowledge regardless of its origins. Goedaert had no training in natural history, and he probably did not read Latin. His work is innocent of the long literary tradition that lies behind Aldrovandi's and Moffett's tomes; though his publisher insisted on adding annotations by the Middelburg physician Joannes de Mey, Goedaert insisted that his own text reported only what he himself had observed (Goedaert 1662-69:vol. 1:sig. c1r-c2v). It is also innocent of any theory of insect reproduction (or generation, in

contemporary terms). Goedaert drew what happened. Like Aldrovandi and Moffett, he was unaware that caterpillars were parasitized by ichneumons and blowflies (Aldrovandi 1602:206,218; Moffett 1634:45-46).

Like Hoefnagel, Goedaert thought that insects revealed God's wonders – but only to the careful observer who could uncover them and, like Goedaert, bring them to light "for the honor of God and the delight of all nature-investigators" (Goedaert 1662-69:vol. 1:sig. a8v-b1r). In the preface to his second volume, Goedaert expanded on this praise – and defense – of natural history, citing Solomon, Cicero, and other eminent predecessors to justify the years he had spent tracing the transformations of insects. But unlike Hoefnagel, Goedaert did not identify emblematic wisdom in nature. He studied insects not because they could tell man how to act but because, as his contemporary Robert Hooke also argued, they revealed God's hidden workmanship (Hooke 1665; cf. Ogilvie 2005).

Martin Lister and Jan Swammerdam: natural order

Martin Lister was sympathetic to Goedaert's methods but critical of his naiveté and lack of order. During the 1670s, in York, Lister was studying spiders in the same way that Goedaert studied caterpillars and their transformations: through careful observation over time of specimens that he had caught or received from friends (Unwin 1995:220). He acquired the Latin translation of Goedaert and rendered it in English, reorganizing it according to his own notions of systematics. In his introduction, Lister blows hot and cold: Goedaert made beautiful drawings but wrote little and left his work in a mess. He spent forty years observing insects, but scarcely seems to have improved in his observing. His observations are "every where very just, and true," but cursory and sometimes unintelligible. He only noted down and drew the changes he saw himself,

> so he committed little or nothing to Writing or Designe, but what succeeded with him, and (as he understood it) had its right Change: Which is more, than any man ever did before him; So that we need not admire, that so long, and pertinatious an Industry produced so few Historys: For he Designed not all, that came to hand, but such only, as it was his good fortune to Feed, and bring up to Change. And yet in these few Historys, you will have something of all the severall Genus's of Insects, that are in Nature (Lister in Goedart 1682:sig. A3r-v).

Lister had Goedaert's plates re-engraved on copper; since booksellers would not underwrite illustrations, Lister made only 150 copies at his expense. "And upon this occasion I must needs say, that Naturall History is much injured, through the little incouragement, which is given to the Artist, whose Noble performances can never be enough rewarded; being not only necessary, but the very beauty, and life of this kind of learning" (Lister in Goedaert 1682:sig. A4r).

Lister's criticisms are fourfold. First, Goedaert discussed relatively few species, though more than his predecessors. He was too sparing with his words – despite Lister's praise for art, he was convinced that it made sense only when explained in words. And Goedaert did not arrange his material in any methodological order. To remedy

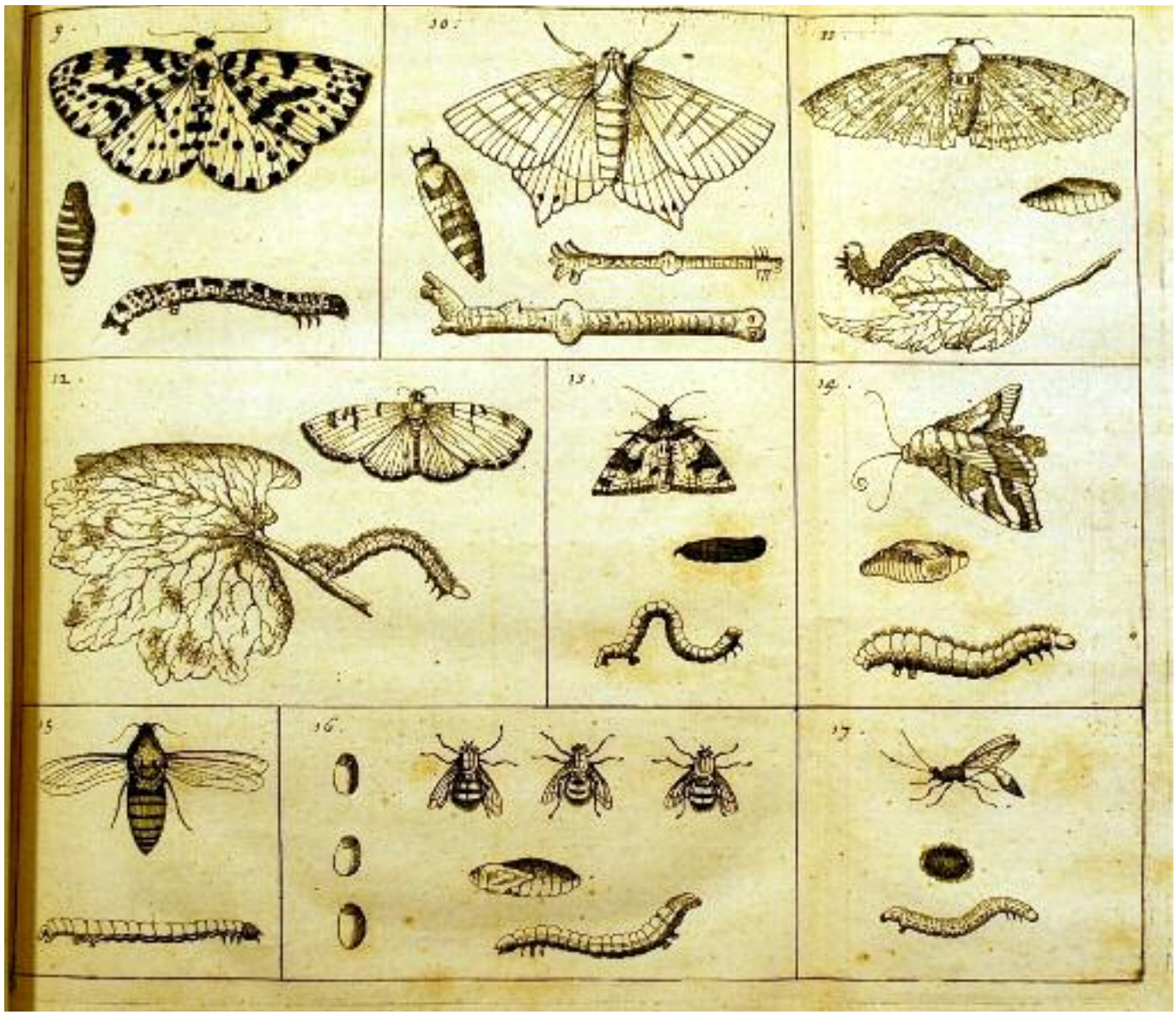

Figure 3. Martin Lister systematized Goedaert's observations, and he had the individual figures re-engraved. Source: Johannes Goedaert, Godartius of Insects, edited and translated by Martin Lister (1682), courtesy of the Entomology, Fisheries & Wildlife Library, University of Minnesota; photo by the author.

this defect, Lister reorganized it and had Goedaert's engravings redrawn following his own order (he included cross-references to the Latin edition on which he based his text). Another fault was more grave, though: Lister knew about the ichneumon, and he repeatedly taxed Goedaert with failing to distinguish between "by-births" and "genuine" transformations of the insect (Goedaert 1682:72). As a result, his illus-

trations and descriptions were not as instructive as they might be: at least, not unless they were annotated and corrected by a naturalist like Lister. Goedaert's eye saw very well the changes that occurred in his individual specimens, but because he lacked a clear idea of natural order and its subversion, the changes he portrayed were equivocal. Though Goedaert often observed the same kind of caterpillar multiple times, his illustrations convey, at least in their diachronic element, some of the individualism that characterizes the *trompe-l'oeil* tradition. They persuaded Lister that Goedaert was an accurate observer but that he all too often did not understand what he observed

Another of Goedaert's critics, the tormented genius Jan Swammerdam, was similarly critical of Goedaert's naive eye. (On Swammerdam's turbulent life, see Schierbeek 1947 or 1967.) Like Lister, Swammerdam recognized the value of Goedaert's work but criticized it vehemently, though he surmised that some of Goedaert's faults were introducd by his publisher (Swammerdam 1685:44-46, 111). Swammerdam's principal objection to Goedaert is that he did not really understand the insect life-cycle; like Lister, Swammerdam thought that Goedaert's ignorance vitiated much of his accomplishment. Swammerdam was fascinated by insect metamorphosis. His illustrations portrayed not only the different stages of the insect's life but also, unlike Goedaert, the moment of transformation itself (Swammerdam 1685:186ff., plate 10). In his first entomological publication, the *Historia generalis insectorum* (written in Dutch; I have used the French translation), Swammerdam used metamorphoses as the basis for an audacious new classification of insects.

The distinction between normal and abortive transmutations was thus essential for Swammerdam, who was obsessed with order in nature as the sign of God's handiwork and dismayed by the work required to observe it.

> Now it is certain that God's works are based on constant and uniform rules, and that we do not know at all the true causes of the effects that we see. And since we know only the shadow of his marvels, we believe firmly that the true knowledge of philosophers consists only in the distinct idea that they can have of the effects that strike their eyes. For that reason, to understand those effects, to form certain rules, and to draw the correct consequences, we must employ every imaginable care and diligence (Swammerdam 1685:163).

Observation was thus the only key to true philosophy, and it was philosophical knowledge of insects to which Swammerdam aspired, knowledge that would ultimately be part of a natural theology. Hence, unlike his compatriot Goedaert, Swammerdam elaborated a theory of observation and its relation to reason. He drew from Descartes the notion of clear and distinct ideas, though he derived them from the senses. He cited Harvey (another of his whipping-boys) approvingly on the dangers of relying on authorities, which leads one to accept as true what is merely plausible. And he drew on Boyle's justification of observing and experimenting. He concluded, "I admit freely that one must be extremely puffed up with pride to maintain that our reasoning can lead us to every truth in the world. On the contrary, we see that it is by using our senses properly that we can, through knowledge of visible

things, understand the truth of things we cannot see" (Swammerdam 1685:169).

In the 1669 history of insects, Swammerdam instantiated this commitment to seeing with reason. His goal in the work was to overturn what he saw as the common belief that insects underwent a radical metamorphosis from one kind of creature to another. Swammerdam wished to depict what was in fact "the slow and almost imperceptible manner in which thir limbs grow" (Swammerdam 1685:t.p., 1). To do this, he had to demonstrate that the apparently swift, radical transformations of some insects from larva to pupa and pupa to imago disguised a slower process of change that lay beneath the surface.

This task would ultimately lead Swammerdam to the detailed micro-anatomies which he conducted in the 1670s and that were published posthumously in the *Bybel der Natuure* (Swammerdam 1737-38; Cobb 2002). In the 1669 book, though, Swammerdam limited himself to what could be seen if an insect were examined closely on the surface. The plates of the *Historia generalis insectorum* display the results. Swammerdam seems to have used a lens or low-powered microscope to examine insects, and he removed the pupal case to demonstrate underneath the slowly forming limbs of the adult insect. The plates reflect long hours of observation and careful delineation on Swammerdam's part. They are also part of Swammerdam's deliberate attempt to persuade his readers of two things. First, the limbs of insects do develop slowly; the metamorphosis is not a complete transformation. Second, there are four main ways in which insects transform, and those transformations can serve as the basis of a classification. The pictures serve as evidence for the first claim: they show what Swammerdam, with his patience and skill, was able to accomplish.

Conclusion

In the end, we see that Swammerdam would not have considered *The Bible of Nature* to be a strange title. The natural order that he had identified in insect transformations was the sublime expression of God's rational order. Martin Lister agreed, as would other proponents of natural theology in the late seventeenth century (Gillespie 1987). Swammerdam and Lister agreed with Goedaert that insects were wondrous, but their experience of wonder drove them to seek an underlying order (cf. Daston and Park 1998). It was quite distinct from the wonder of Goedaert in the transformations themselves, or in Aldrovandi's and Hoefnagel's wonder at the intricate anatomy of each individual insect. In 1613, the Jesuit theologian Leonard Lessius had remarked that the organs of insects were so finely wrought as to be "incomprehensible to mans wit"; they "procure an astonishing admiration in whom behold them attentively," revealing "the art of divyne Providence" in their fabrication (Lessius 1631:102-103,109). Swammerdam felt the same wonder, but it spurred him to find ways to comprehend even the minutest organs.

But of course, earlier students of insects had also sought order. Aldrovandi's order was that of the collector, organizing specimens synchronically into rational and beautiful patterns, and presenting them with their accumulated lore. Hoefnagel's order was that of insect syntax – the shape and organization of its parts – and insect semantics – the emblematic meanings that insects vouchsafed humanity. Goedaert's order was the temporal order of transfor-

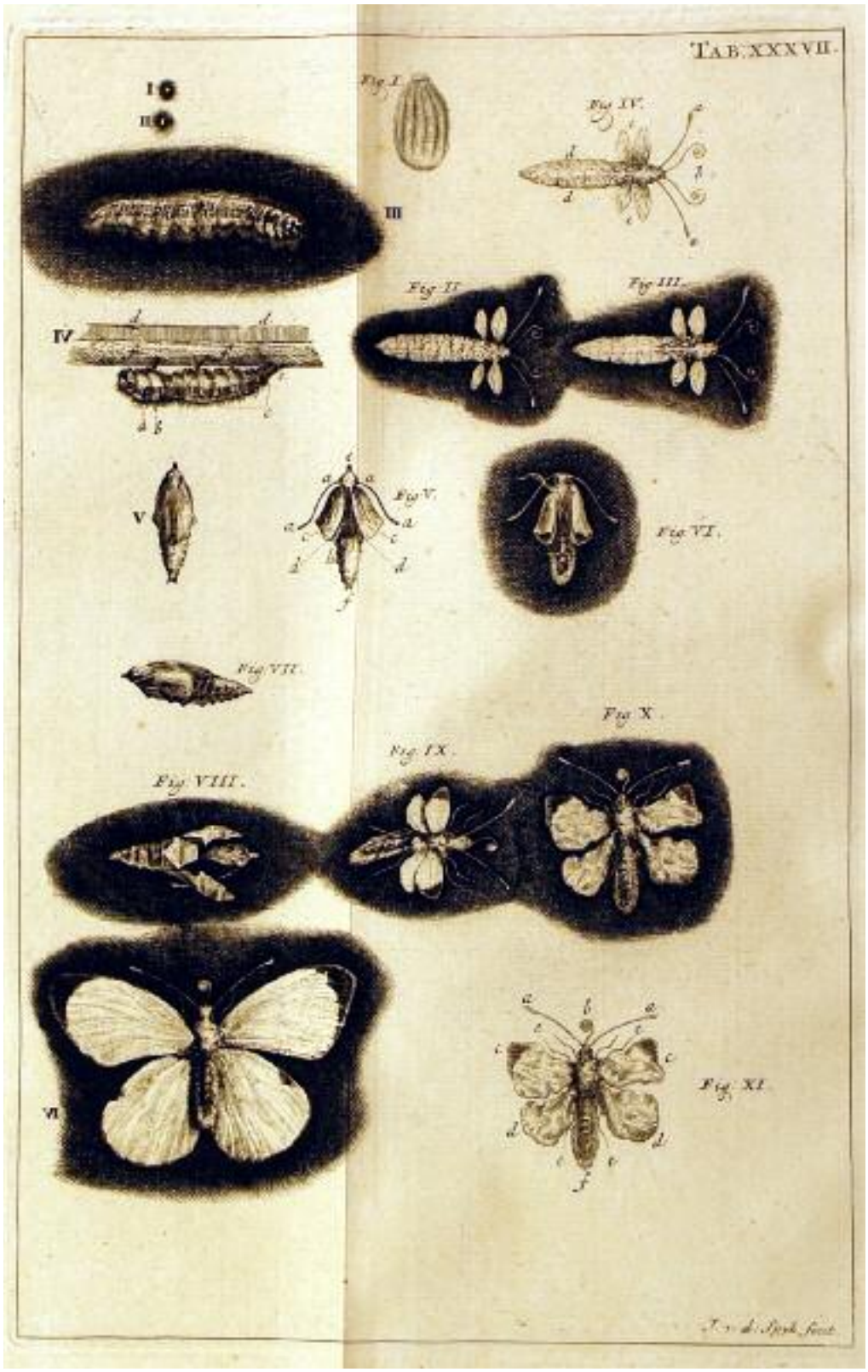

Figure 4.
This engraving by Jan Swammerdam details the successive stages of a butterfly's life. Swammerdam classified insects according to the nature of their transformations. Swammerdam prepared the image in the 1670s but it was not published until over half a century after his death. Source: Jan Swammerdam, Bybel der natuure (1738), courtesy of the Entomology, Fisheries & Wildlife Library, University of Minnesota; photo by the author.

Figure 5.
Maria Sibylla Merian depicted larvae, pupas, and adult insects next to the plant hosts on which the adults laid eggs and the larvae ate. Source: Maria Sibylla Merian, Erucarum hortus (1717), courtesy of the Entomology, Fisheries & Wildlife Library, University of Minnesota; photo by the author.

mation. Swammerdam's contemporary Maria Sibylla Merian studied, like Goedaert, transformations, but she added an ecological order, going to Surinam to study not only insects themselves but the plants on which they lived (Schneider 1991; Davis 1995).

Many of these orders would coalesce, toward the middle of the eighteenth century in the new discipline of entomology. Morphological description, anatomical investigation, and classification – based on Swammerdam's studies of metamorphosis – all would have their place. When in the 1730s Hermann Boerhaave acquired the manuscript of *The Bible of Nature*, he swiftly arranged for it to be translated into Latin and published; in over half a century Swammerdam's work had not been equaled, let alone surpassed. That would swiftly change, with the work of René-Antoine Ferchauld de Réaumur and Charles Bonnet, and entomology would quickly develop into a distinctive discipline.

Before entomology, though, orders of insects were pursued by several different investigators of nature. We can situate each in particular contexts: Aldrovandi the Renaissance collector and encyclopedist; Hoefnagel the miniaturist and court artist; Goedaert the landscape painter, miniaturist, and amateur; Swammerdam and Lister the physicians and anatomists. (One could add Outgaert Cluyt, Jacopo Ligozzi, Marcello Malpighi, Francesco Redi, John Ray, and others whom I have not been able to discuss.) What is striking about the late sixteenth and seventeenth centuries, though, is that knowledge about insects, in words and pictures, circulated freely between these contexts. Aldrovandi collected illustrations as well as insects. Goedaert's publisher added notes from Aldrovandi to Goedaert's own observations. Swammerdam and Lister critiqued Goedaert severely but admitted the immense value of his work. Merian was inspired by Goedaert as well as by her experiences in Amsterdam curiosity cabinets (Neri 2003:175ff.). In Renaissance, Baroque, and early Enlightenment Europe, insects flew, hopped, or crawled across disciplinary boundaries, bringing knowledge and wonder in their train.

References

Albus, Anita 2000. *The art of arts: Rediscovering painting*. New York, Alfred A. Knopf.

Aldrovandi, Ulisse 1602. *De animalibus insectis libri septem*. Ioan. Bapt. Bellagamba, Bologna.

Aldrovandi, Ulisse 2005. *Pinakes Ulisse Aldrovandi*. [Online] Università di Bologna. URL:
http://www.filosofia.unibo.it/aldrovandi/pinakesweb/main.asp?language=it. [Accessed 4 March 2005]

Ashworth, William B., Jr. 1990. "Natural history and the emblematic world view." In David C. Lindberg and Robert S. Westman (eds.): *Reappraisals of the Scientific Revolution*. Cambridge, Cambridge University Press.

Bocskay, Georg, and Joris Hoefnagel 1992. *Mira calligraphiae monumenta: A sixteenth-century calligraphic manuscript inscribed by Georg Bocskay and illuminated by Joris Hoefnagel*. Edited by Lee Hendrix and Thea Vignau-Wilberg. Los Angeles, J. Paul Getty Museum.

Bodenheimer, F. S. 1928. *Materialien zur Geschichte der Entomologie bis Linné*. Berlin, W. Junk.

Cambefort, Yves 2006. "A sacred insect on the margins: Emblematic beetles in the Renaissance." In Eric C. Brown (ed.): *Insect poetics*. Minneapolis and London, University of Minnesota Press.

Cobb, Matthew 2002. "Malpighi, Swammerdam and the colourful silkworm: Replication and visual representation in early modern science." *Annals of Science*, vol. 59, pp. 111-47.

Cobb, Matthew 2006. *Generation: The seventeenth-century scientists who unraveled the secrets of sex, life, and growth*. New York, Bloomsbury USA.

Daston, Lorraine, and Katharine Park 1998. *Wonders and the order of nature, 1150-1750*. New York, Zone Books.

Davis, Natalie Zemon 1995. *Women on the margins: Three seventeenth-century lives*. Cambridge, MA, Harvard University Press.

Dommann, Monika 2004. "Vom Bild zum Wissen: Eine Bestandaufnahme wissenschaftshistorischer Bildforschung." *Gesnerus*, vol. 61, pp. 77-89.

Essig, E. O. 1936. "A sketch history of entomology." *Osiris*, vol. 2, pp. 80-123.

Findlen, Paula 1994. *Possessing nature: Museums, collecting, and scientific culture in early modern Italy*. Berkeley and Los Angeles, University of California Press.

Freedberg, David 2002. *The eye of the lynx: Galileo, his friends, and the beginnings of modern natural history*. Chicago and London, University of Chicago Press.

Funkenstein, Amos 1986. *Theology and the scientific imagination from the middle ages to the seventeenth century*. Princeton, Princeton University Press.

Gillespie, Neal, C. 1987. "Natural history, natural theology, and social order: John Ray and the "Newtonian Ideology"." *Journal of the History of Biology*, vol. 20, pp. 1-48.

Goedaert, Johannes 1662-69. *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 vols. Jaques Fierens, Boeckverkooper, inde Globe, Middelburg.

Goedaert, Johannes 1682. *Of insects: Done into English and methodized with the addition of notes*. Edited and translated by Martin Lister. Printed by John White for M. L., York.

Goldgar, Anne 2007. *Tulipmania: Money, honor, and knowledge in the Dutch gold-*

en age. Chicago and London, University of Chicago Press.

Harms, Wolfgang 1989. "Bedeutung als Teil der Sache in zoologischen Standardwerken der frühen Neuzeit (Konrad Gesner, Ulisse Aldrovandi)." In Hartmut Boockmann (ed.): *Lebenslehren und Weltentwürfe im Übergang von Mittelalter zur Neuzeit*. Göttingen, Vandenhoeck & Ruprecht.

Hendrix, Lee 1995. "Of hirsutes and insects: Joris Hoefnagel and the art of the wondrous." *Word & Image*, vol. 11, pp. 373-90.

Hooke, Robert 1665. *Micrographia, or, Some physiological descriptions of minute bodies made by magnifying glasses with observations and inquiries thereupon*. London, Jo. Martyn and Ja. Allestry.

Kaufmann, Thomas DaCosta 2007. Personal communication. Princeton, NJ, November 9.

Kaufmann, Thomas DaCosta, and Virginia Roehrig Kaufmann 1993. "The santification of nature: Observations on the origins of trompe l'oeil in Netherlandish book painting of the fifteenth and sixteenth centuries." In *The mastery of nature: Aspects of art, science, and humanism in the Renaissance*. Princeton, Princeton University Press.

Kelley, Donald (ed.) 1997. *History and the disciplines: The reclassification of knowledge in early modern Europe*. Rochester, NY, University of Rochester Press.

Koreny, Fritz 1988. *Albrecht Dürer and the animal and plant studies of the Renaissance*. Boston, Little, Brown and Company.

Lessius, Leonardus 1631. *Rawleigh his ghost; Or, a feigned apparition of Syr Walter Rawleigh to a friend of his, for the translating into English, the booke of Leonard Lessius (that most learned man) entituled, De prouidentia numinis, & animi immortalitate: written against atheists, and polititians of these dayes*. No location [Saint-Omer?]. Original Latin edition published 1613.

Moffett, Thomas 1634. *Insectorum sive minimorum animalium theatrum*. London, William Hope.

Neri, Janice 2003. "Fantastic observations: Images of insects in early modern Europe." Ph.D. diss, Visual Studies, University of California, Davis.

OED 2005. *Oxford English dictionary online*. Oxford University Press. URL: http://dictionary.oed.com. [Consulted 4 February 2005]

Ogilvie, Brian W. 2003. "Image and text in natural history, 1500–1700." In Wolfgang Lefèvre, Jürgen Renn, and Urs Schöpflin (eds.): *The power of images in early modern science*. Basel, Birkhäuser Verlag.

Ogilvie, Brian W. 2005. "Natural history, ethics, and physico-theology." In Gianna Pomata and Nancy Siraisi (eds.): *Historia: Empiricism and erudition in early modern Europe*. Cambridge, MA, MIT Press.

Ogilvie, Brian W. 2006. *The science of describing: Natural history in Renaissance Europe*. Chicago, University of Chicago Press.

Olmi, Giuseppe 1992. *L'inventario del mondo: Catalogazione della natura e luoghi del sapere nella prima età moderna*. Bologna, Il Mulino.

Pickstone, John V. 2007. "Working knowledges before and after 1800: Practices and disciplines in the history of science, technology, and medicine." *Isis*, vol. 98, pp. 489-516.

Pinon, Laurent 1995. *Livres de zoologie à la Renaissance: Une anthologie, 1450-1700. Corpus iconigraphique de l'histoire du*

livre. Paris, Klincksieck.

Rossi, Paolo 1984. *The dark abyss of time: The history of the earth and the history of nations from Hooke to Vico*. Chicago and London, University of Chicago Press.

Ruestow, Edward G. 1996. *The microscope in the Dutch Republic: The shaping of discovery*. Cambridge, New York, and Melbourne, Cambridge University Press.

Schierbeek, A. 1947. *Jan Swammerdam, 12 Februari 1637-17 Februari 1680: Zijn leven en zijn werken*. N. V. Uitgeversmaatschappij "De Tijdstroom", Lochum.

Schierbeek, A. 1967. *Jan Swammerdam, 12 February 1637-17 February 1680: His life and works*. Amsterdam, Swets & Zeitlinger.

Schneider, Christiane 1991. "'Sibylle à Surinam va chercher la nature.' Maria Sibylla Merians Metamorphosis insectorum Surinamensium." In Regina Pleithner (ed.): *Reisen des Barock: Selbst- und Fremderfahrungen und ihre Darstellung*. Bonn, Romantistischer Verlag.

Swammerdam, Jan 1685. *Histoire generale des insects: Ou l'on expose clairement la maniere lente & presqu'insensible de l'accroissement de leurs membres, & ou l'on decouvvre evidemment l'Erreur ou l'on tombe d'ordinaire au sujet de leur prétendué transformation*. Utrecht, Jean Ribbius.

Swammerdam, Jan 1737-38. *Bybel der natuure.of Historie der insecten tot zeekere zoorten gebracht*. Edited by Hermann Boerhaave. 2 vols, by I. Severinus, Leyden.

TLF 2005. *Trésor de la langue française informatisé*. [Online] ATILF. http://atilf.atilf.fr/tlf.htm. [Consulted 4 February 2005]

Unwin, Robert W. 1995. "A provincial man of science at work: Martin Lister, F.R.S., and his illustrators, 1670-1683." *Notes and Records of the Royal Society of London*, vol. 49, pp. 209-30.

Van der Pas, Peter W. 1970. "Goedaert, Johannes (b. Middelburg, Netherlands, ca. 19 March 1617; d. Middelburg, February 1668)." In Charles Coulton Gillespie (ed.): *Dictionary of Scientific Biography*, vol. 5. New York, Charles Scribner's Sons.

Vignau-Wilberg, Thea 1994. *Archetypa studiaque patris Georgii Hoefnagelii 1592: Natur, Dichtung und Wissenschaft in der Kunst um 1600: Nature, poetry and science in art around 1600*. München, Staatliche Graphische Sammlung.

Wiener, Philip P. 1940. "Leibniz's project of a public exhibition of scientific inventions." *Journal of the History of Ideas*, vol. 1, pp. 232-40.

Wilson, Catherine 1995. *The invisible world*. Princeton, NJ, Princeton University Press.