THE BOOK OF NATURE:

JAN SWAMMERDAM'S MICROSCOPICAL INVESTIGATIONS

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Introduction

It is generally recognized in the history of the life sciences that microscopy occupied a position in the front line of research during the second half of the seventeenth century. The names of Robert Hooke, Marcello Malpighi, Nehemiah Grew, Jan Swammerdam and Antoni van Leeuwenhoek are indissolubly linked with the memorable discoveries made in that period with the aid of the microscope. It is also generally acknowledged that scientific microscopy was at a very low level during the greater part of the eighteenth century, while at the same time the microscope was a fashionable toy for the well-to-do. What is less generally appreciated is that the microscope had been invented for nearly half a century by the time it began to be fairly widely employed in science. Thus the period in which Malpighi first described the capillaries of the blood system (1661), Hooke discovered the confines of what is now called the plant cell (1664), and Van Leeuwenhoek discovered the spermatozoa (1677) appears in the history of the life sciences as a solitary and brief interval of productive research in the two centuries between the invention of the microscope and the formulation of the cell theory, which was to generate a vast field of microscopical investigation.

The characterization of this first period of growth in microscopy as an isolated episode gives rise to various questions, such as why the microscope was not employed in science earlier, why scientists suddenly began to exploit that instrument, and why it was so quickly discarded despite various widely appreciated results. One can think of several possible answers to these questions. The microscope could have been much improved immediately prior to 1660, and consequently the microscopical investigation of natural phenomena could begin in earnest only at that point. Alternatively it may have been coincidence that five men in different European countries began, precisely in that period, to use a microscope for their investigations with admirable results. In that case the decline of microscopy would be attributable merely to the death of these men.

Tractrix 2, 1990, pp. 1-24.

With a view to resolving such questions I began to analyse of the substance of the first flourishing of microscopy in the seventeenth century.[1] For the purposes of this enquiry I have studied the goals and efforts of the above-mentioned five eminent microscopists of that period. I have analysed their published works from various perspectives, viz., their conceptions of nature and of scientific enquiry; the main content of their microscopical research; and the theories they evolved from that research. From my study it appears that, generally speaking, the primary inducement to use of the microscope stemmed from a concern with the fundamental processes of life, particularly with the formation of organic matter from inorganic matter and the operation of the animal 'oeconomy'.

The microscopical work of Jan Swammerdam, however, forms an exception to this rule. The incentive for his unprecedented microscopical examination of insect anatomy stemmed basically from his veneration for the infinite complexity of God's handiwork. He regarded its scientific exploration as a form of worship. Since, in Swammerdam's view, God's majesty implies that it is impossible to arrive at certain knowledge of the ultimate causes of life's processes, the emphasis in his microscopical work is on accurate description rather than on the animal 'oeconomy'. Swammerdam's uncompromising nature, which deeply influenced his conception of scientific enquiry, is apparent both in the choices he made in his personal life and in his scientific work.

Jan Swammerdam

Swammerdam's personal life was anything but harmonious.[2] His passionate devotion to scientific investigation was at the root of the most severe and prolonged of the various conflicts that disrupted his life.

One of these conflicts arose when Swammerdam preferred to study medicine rather than theology, a choice to which his father apparently only grudgingly consented. This conflict spoiled his relations with his family, particularly with his father, from his student days until his father's death. As a student at Leyden University Swammerdam did not restrict himself to the prescribed curriculum but started to experiment on his own account. Some of his experiments are described

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[1] This study will shortly be published under the title *The fabric of life, an analysis of seventeenth-century microscopy.*

[2] Herman Boerhaave, "Het leven van den heer Jan Swammerdam," in Jan Swammerdam, *Biblia Naturae,* 2 vols. (Leyden: Isaak Severinus, Boudewyn van der Aa, Pieter van der Aa, 1737-1738), vol. 1, pp. 15-49; Abraham Schierbeek, *Jan Swammerdam (12 Februari 1637 - 17 Februari 1680). Zijn leven en zijn werken* (Lochem: De Tijdstroom, 1947); Gerrit A. Lindeboom, "A short biography of Jan Swammerdam (1637-1680)," in *The letters of Jan Swammerdam to Melchisedec Thévenot*, ed. Gerrit A. Lindeboom (Amsterdam: Swets & Zeitlinger, 1975), pp. 3-34; Gerrit A. Lindeboom, "Jan Swammerdam (1637-1680) and his Biblia Naturae," *Clio Medica* 17, 1982, pp. 113-131; Mary P. Winsor. "Swammerdam, Jan," in *Dictionary of Scientific Biography*, ed. Charles G. Gillispie, 16 vols. (New York: Charles Scribner's Sons, 1976), vol. 13, pp. 168-175.

in the diary of Ole Borch,[3] a professor from the University of Copenhagen, who stayed for a few months in Leyden during a prolonged tour of various European universities. Swammerdam's future interests and skills are already apparent from Borch's entries. On various occasions he displayed his cabinet of insects to Borch, performed some experiments with live dogs and demonstrated, in connection with Malpighi's recently published *De pulmonibus*, the alveoli of a frog's lung.

Despite these promising indications, Swammerdam delayed the formal completion of his studies by absenting himself for three years from Leyden University. Part of this period was occupied by a prolonged sojourn in France. When he had finally become a doctor of medicine in 1667 by presenting and defending a doctoral thesis entitled *De respiratione*, Swammerdam settled in Amsterdam. There, he did not take up the practice of medicine in order to earn a living, but devoted his time to scientific interests, living at his father's expense. This state of affairs caused such tension between father and son that Swammerdam once wrote to his friend Melchisedec Thévenot that he was going to give up "anatomy, insects and all curious experiments," being forced to that decision because his father was "no more inclined to provide ... money or clothes."[4] However, his father apparently relented, as Swammerdam continued to live in his father's house and went on with his research without interruption. In order to ensure financial independence from his father, Swammerdam eventually decided to sell his cabinet of natural curiosities. In 1668 no less than 12,000 guilders had been offered for that collection[5] (after which time the collection was again substantially enlarged)[6] and as Swammerdam estimated that he only needed 400 guilders a year to sustain him, the sale of his cabinet would definitely resolve his difficulties. However, the sale of the cabinet did not come off and neither did the sale of his father's cabinet some years later. The Swammerdam siblings quarrelled over their father's estate, so that the sale of Swammerdam *père's* cabinet, which would have meant a future free from financial worries for his son, did not take place until after Swammerdam had died. In sum, Swammerdam's relations with his family were strained throughout his adult life mainly because he wanted to devote his time to scientific investigations rather than earn his own living.

A second conflict raged in Swammerdam's own mind between his passion for

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[3] *Olai Borrichii Itinerarium 1660-1665: the journal of the Danish polyhistor Ole Borch*, ed. H.D. Schepelern, 4 vols. (Copenhagen: Reitzels Forlag, 1983), vol. 2, pp. 269-72, 299; Johan Nordström, "Swammerdamiana. Excerpts from the travel journal of Olaus Borrichius and two letters from Swammerdam to Thévenot," *Lychnos* 1954-1955, pp. 21-65.

[4] Gerrit A. Lindeboom ed., *The letters of Jan Swammerdam to Melchisedec Thévenot* (Amsterdam: Swets & Zeitlinger, 1975), p. 54.

[5] Swammerdam was offered this sum by the Duke of Tuscany, but declined because the offer entailed that he come and take care of the collection in Italy, see Lindeboom (n. 4), *Letters of Swammerdam to Thévenot*, p. 72.

[6] Jan Swammerdam, "Le cabinet de Mr.Swammerdam, docteur en medecine, ou catalogue de toutes sortes d'insectes," in Melchisedec Thévenot, *Receuil des Voyages* (Paris, 1681); Gerrit A. Lindeboom, *Het cabinet van Jan Swammerdam (1637-1680). Catalogus met een inleiding uitgegeven door* ... (Amsterdam: Rodopi, 1980).

science on the one hand and his deep religious feelings on the other. Nearly every second page in his *Biblia Naturae* testifies to his belief that God's omnipotence is nowhere more visible than in the intricate structure of minute living beings. A typical declaration of his feelings is the following paragraph:

> Look, so all-wonderful is GOD, in respect of these small animals, so that I dare say, that in the insects GOD'S countless wonders are sealed up, which seals are revealed as one diligently turns over the leaves of the book of Nature, the Bible of Natural Theology, in which GOD'S invisibility becomes visible; because treasuries of ineffable wonders then manifest themselves; and the hidden Creator becomes so manifest in these small Animals, that the experiences of the same, serve me as the biggest proofs to evince without yielding his eternal Divinity and Providence against all his detractors.[7]

Swammerdam conceived the study of nature as an exploration and confirmation of God's glory, and thus as a kind of divine worship. However, his investigations were also a time-consuming occupation, which prevented the giving of due attention to traditional forms of worship. Over the years Swammerdam came to feel that, by indulging in scientific research, he was neglecting his vital duties as a Christian. In the preface to *Ephemeri Vita*, dated 12 July 1675, he wrote,

> I have now spent enough time and labour in the investigation of Nature and have followed my own depraved will and pleasure therein. Wherefore I now intend to follow solely God's will, to surrender my will to Him, and withdraw all my thoughts from the multiple things so as to offer them to heavenly reflections only.[8]

Swammerdam was obviously trapped in a crisis, struggling with conflicting desires. In the end this resulted in a decision to renounce scientific research and to join the religious community of Antoinette Bourignon. This decision was supported by his feeling that his investigations "have already served me as a ladder to climb up to Him, and one does no longer need the means once the goal has been reached. For, if one continues to wish to use the means, they become nothing but impediments."[9]

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[7] Jan Swammerdam, *Biblia Naturae* (Leyden: Isaak Severinus, Boudewyn van der Aa, Pieter van der Aa, 1737-1738), p. 394: "Siet, soo oververwonderlyk is GOD, ontrent deese kleene Beeskens, soo dat ik durf seggen, dat ontrent de Insecten GODS onnoemelyke wonderen versegelt syn, ende dewelke segelen zig komen te openen, als men het boek der Natuur, de Bybel van Natuurelyke Godsgeleertheid, en waar in GODS Onzienelykheid sigtbaar wort, neerstig komt te doorbladeren; want schatkameren van onnoemelyke wonderen openbaaren haar alsdan; en de verborgene Schepper wort in deese kleene Dierkens soo openbaar, dat de ondervindingen omtrent deselve, my voor de allergrootste bewysen dienen, om syne eeuwige Goddelykeheid ende Voorsienigheid, tegens alle syne ontkenners onversettelyk te bewysen."

[8] Jan Swammerdam, *Ephemeri Vita Of afbeeldingh van 's menschen leven* ... (Amsterdam: Abraham Wolfgang, 1675), preface p. 5: "Ick heb nu langh genoegh mijn tijt ende arbeyt besteedt, in het ondersoecken van de natuur, ende mijn verdurve eyge wil ende behaagen daar in gevolght. Waarom ick nu voorneem de wille Gods alleen te volgen; mijn wil aan hem over te geeven; ende alle mijne gedachten van de meenighvuldigheeden af te trecken, om die alleenigh aan hemelsche bedenckingen op te offeren."

[9] *Ibid.*, p. 87: " ... sy my als een ladder, om tot hem opwaarts klimmen, alreede gedient hebben; ende dat men niet langer de middelen van doen heeft, als men het eynde heeft bekomen. Want als men dan noch de middelen gebruycken wil, so synse niet, als beletselen."

However, from the circumstances that delayed his departure to Bourignon's side it is clear that Swammerdam's mind was still inclined to science. He first saw his treatise on the mayfly, entitled *Ephemeri Vita*, through the press. This book is a perfect reflection of his state of mind at the time. It is a mixture of a superb study of the life and anatomy of the mayfly (see figures 1 and 2), of lamentations on the futility of human life, of prayers and of digressions into theological questions. Before he left Amsterdam Swammerdam also went through the notes of his researches and destroyed some of these, among them his notes on the anatomy of the silkworm. However, most of his notes were still extant when he resumed his scientific activities about a year later, and he took care that his drawings of the silkworm's interior parts were sent to Malpighi, so that the results of his work would not be lost.[10]

During his stay in Bourignon's community the conflict between science and religion was to some extent resolved in Swammerdam's mind. Upon his return to Amsterdam, he devoted all his time to editing his notes, which he elaborated and completed and which were supplemented with a series of newly initiated investigations.[11] Eventually all of this was to be published as the *Biblia Naturae* through the good offices of Herman Boerhaave, half a century after the author's death.

Swammerdam therefore executed this research, as he frequently stated in personal remarks inserted between detailed descriptions, "solely to the Glory of God and without any other intention."[12] Even though this was a deeply felt sentiment, the connection between his religious and scientific passions was certainly not only stimulating and fertile,[13] but also competitive and, during at least one period in his life, destructive.

The trying circumstances of Swammerdam's private life were balanced by a number of supportive friendships, including those with Niels Stensen and Melchisedec Thévenot. Stensen's life was in several respects a parallel to that of his friend, as he was similarly torn between science and religion.[14] Unlike the former, though, Stensen resolved to follow a professional career in religion. Swammerdam and Stensen first met in Leyden when both were students, and they collaborated in

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[10] Luigi Belloni, "Stensen-Andenken in Italien," in *Steno and brain research*, ed. Gustav Scherz (Oxford: Pergamon Press, 1968), pp. 171-180.

[11] Lindeboom (n. 4), *Letters of Swammerdam to Thévenot*, letters 11 through 40; Lindeboom (n. 1), "Jan Swammerdam and his Biblia Naturae."

[12] Swammerdam (n. 7), *Biblia Naturae*, p. 386: "alleen tot GODS lof, ende sonder eenige andere de minste insigt te vervolgen."

[13] As argued by Änne Bäumer, "Zur Verhältnis von Religion und Zoologie im 17. Jahrhundert. (William Harvey, Nathaniel Highmore, Jan Swammerdam)," *Berichte zur Wissenschaftsgeschichte* 10, 1987, pp. 69-81.

[14] Bento P.M. Schulte, "Swammerdam and Steno," in *Steno and Brain research*, ed. G. Scherz (Oxford: Pergamon Press, 1968), pp. 35-41; Gustav Scherz, "Stensen, Niels," in *Dictionary of Scientific Biography*, ed. Charles G. Gillispie, 16 vols. (New York: Charles Scribner's Sons, 1976), vol. 13, pp. 30-35.

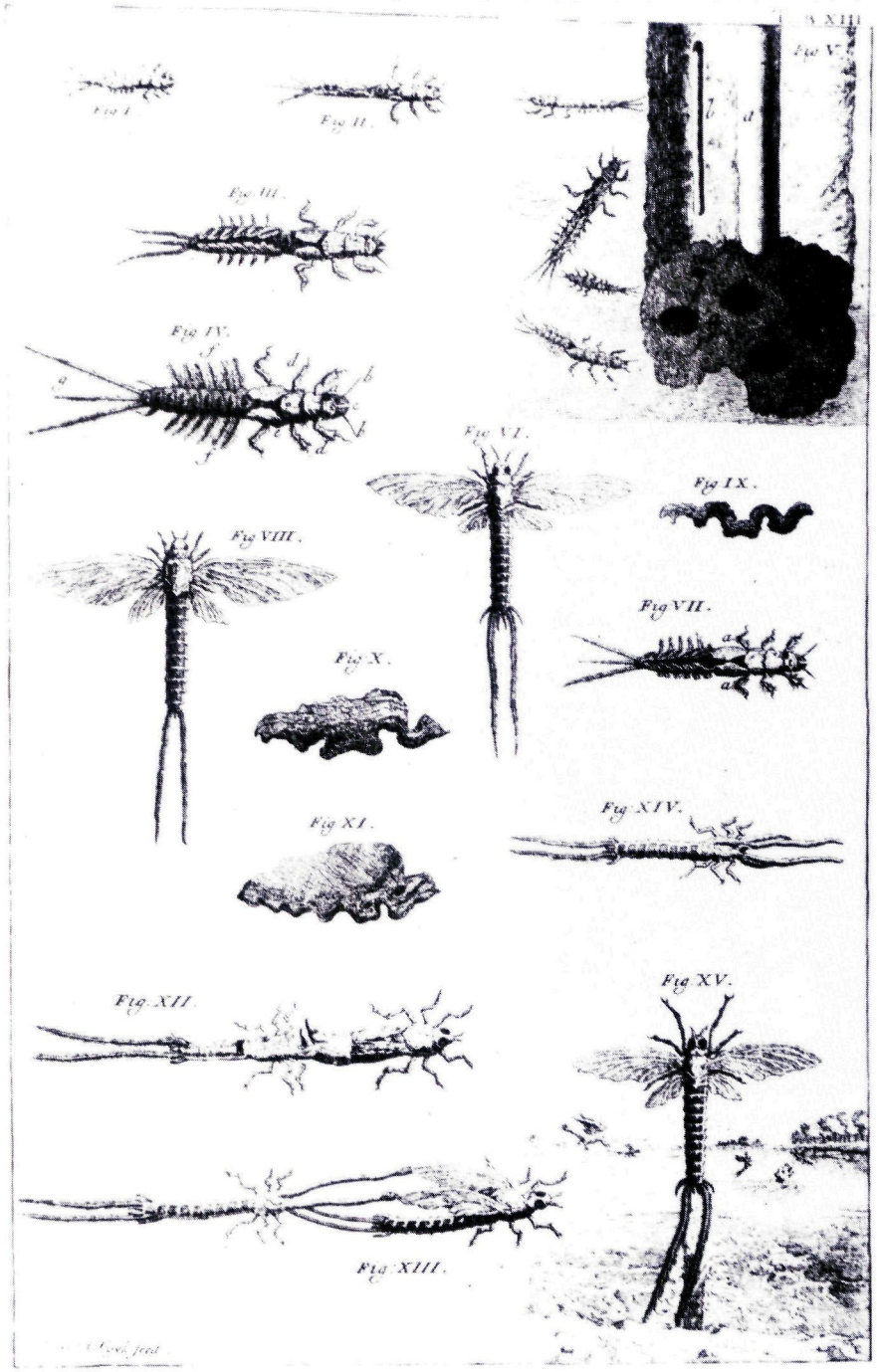

Figure 1 – Life-cycle of the may-fly, Tab. XIII from *Biblia Naturae*.

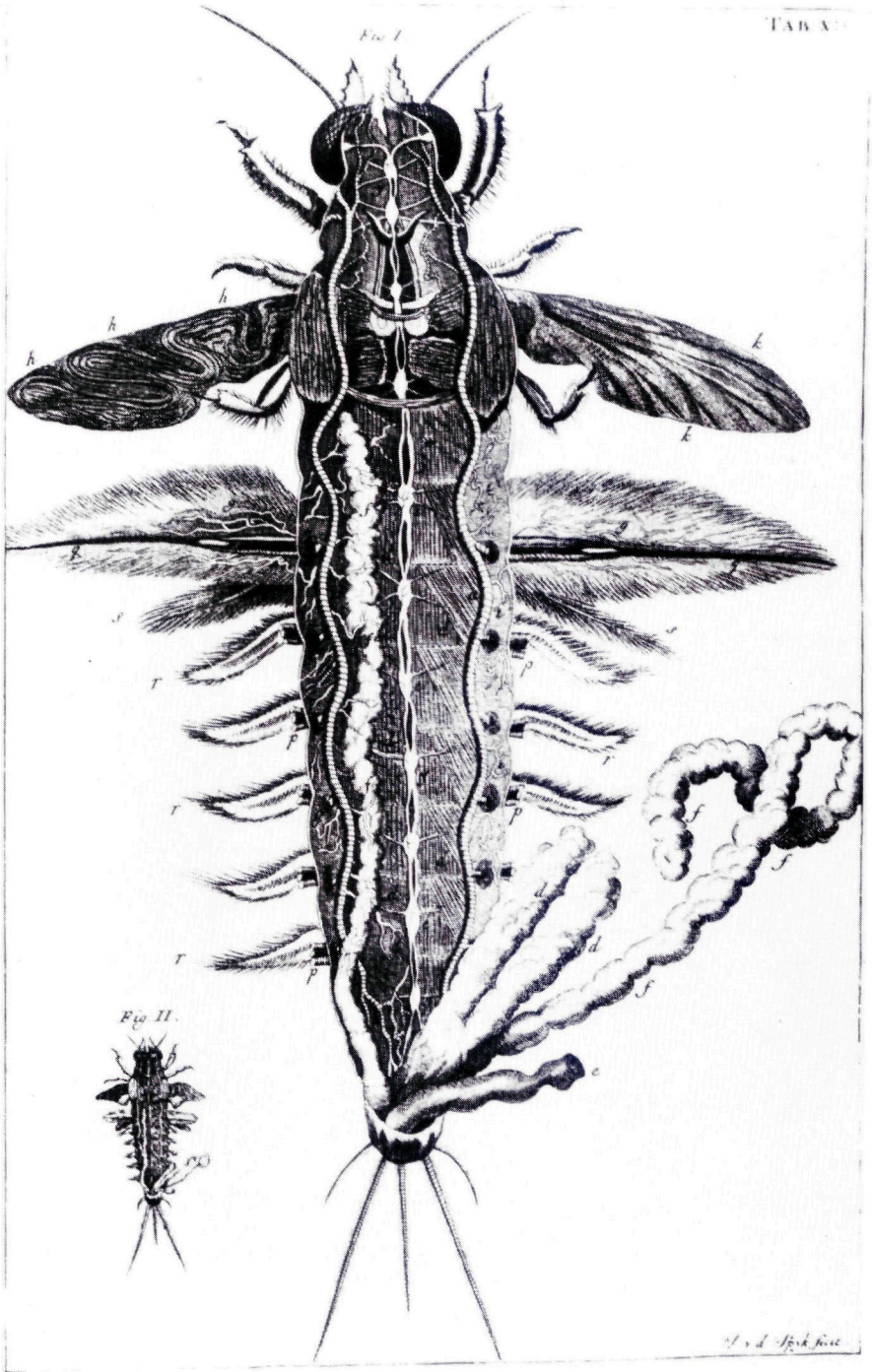

Figure 2 – Anatomy of the larva of the may-fly, Tab. XIV from *Biblia Naturae.*

the investigation of muscles.[15] In subsequent years they met again in Paris when both were drawn into the circle of scholars surrounding Thévenot, which was to become a foundation stone of the *Académie Royale*. Although Swammerdam met both Stensen and Thévenot again in later years, these encounters were only brief, so that most of the scholar's exchanges were enacted through letters.

In Leyden and in Amsterdam Swammerdam found opportunities to perform his research in congenial company. In Leyden he studied with Stensen and Reinier de Graaf under Sylvius, and later worked with Johannes van Horne. In Amsterdam he joined the *Collegium privatum Amstelodamense*, and in fact he dominated the activities of this small body of men,[16] Gerard Blaes being prominent among them. Although Swammerdam was not perturbed when some of his most accomplished anatomical feats, such as the demonstration of the valves in the lymphatic vessels and the structure of the spinal marrow, were published under others' names (Frederik Ruysch,[17] and Gerard Blaes,[18] respectively) he reacted rather uncharacteristically with respect to De Graaf's *De Mulierum organis* (1672). In his polemical *Miraculum Naturae* (1672), which he published directly upon the publication of De Graaf's book, Swammerdam claimed priority for Van Horne, Stensen and himself concerning the discovery of certain details of the human ovaries, which he had already published by means of an engraved plate the year before.[19] This untypical action on the part of Swammerdam may have been prompted by feelings of friendship for Stensen and gratitude for Van Horne's patronage. Be that as it may, his claim was rejected by the Royal Society with whom he had lodged it.[20]

Swammerdam's views on the pursuit of scientific enquiry

Swammerdam was wholeheartedly committed to the empirical method in science. He regarded observation and experience as the prerequisites for any certain knowledge of nature. Knowledge derived solely from books was worthless in his view, and he fulminated against deductive reasoning. Many a philosopher, he wrote,

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[15] Swammerdam (n. 7), *Biblia Naturae*, p. 837; Schulte (n. 13), "Swammerdam and Steno."

[16] Francis J. Cole, *Observationes anatomicae selectiores Amstelodamensium 1667-1673*, ed. Francis J. Cole (Berkshire: University of Reading, 1938), pp. i-xi: "Introduction"; Gerrit A. Lindeboom, "Het Collegium Privatum Amstelodamense (1664-1673)," *Nederlands Tijdschrift voor Geneeskunde* 119, 1975, pp. 1248-1254.

[17] Frederik Ruysch, *Dilucidatio valvularum in vasis lymphaticis, et lacteis* (The Hague: Harmani Gael, 1665).

[18] Gerard Blasius [Blaes], *Anatome medullae spinalis et nervorum inde provenientium* (Amsterdam, 1666).

[19] This engraving was dedicated to Nicolaas Tulp and appeared slightly changed as one of the illustrations in Swammerdam's *Miraculum Naturae* (1672).

[20] Th. Birch, *The history of the Royal Society of London for improving of natural knowledge* ... 4 vols. (London: A. Millar, 1756-1757), vol. 2, pp. 41, 94; Gerrit A. Lindeboom, *Regnier de Graaf Leven en werken 30-7-1641/17-8-1673*, (Delft: Elmar B.V., 1973), pp. 118-119.

had erred to a distressing degree by relying on reasoning while forgetting to observe the phenomena in the first place,[21] an assessment which was substantiated with a reference to the faulty notions of metamorphosis he had encountered in the relevant literature. Swammerdam's published research demonstrates that he kept strictly to his own rules and rarely advocated views that were not supported by the results of his own observations and experiments.[22] He observed, experimented, described and reached conclusions which had, by way of a final test, to be checked against nature. Indeed,

> when our reason is false and wanting; when she cannot be supported by experience; cannot be proved by it, and does not terminate in the same, then it seems to me, that there can be no stronger or more powerful reasons than those which are extracted from experience and practice, in which they must end. All other reasons, which do not have this firm and unmovable foundation, no matter on how many inductions and conclusions they rest, must be regarded with some suspicion, and if they do not accord with experience, they must be discarded entirely.[23]

To Swammerdam the outcome of the process of amassing data and of subsequent induction was a clearer insight into the laws and order prevalent in nature. Although he conceded that, in principle, man might discover causal explanations of the phenomena, in practice he deemed this to be impossible, partly because of the feebleness of man's mind but also as a result of the limitations of man's powers of observation. He argued that

> just as we cannot obtain true experience of all things, and have therefore no clear and distinct notion of the same (like those which are too small for our vision and like others that are too far removed from it), just so we should not foolishly imagine that we shall ever obtain through our reason true and real knowledge of the causes of things, let alone of her true manifestations. Our greatest wisdom lies ... not in knowledge concerning the causes of things but only in a clear and distinct notion of [nature's] true manifestations or effects.[24]

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[21] Swammerdam (n. 7), *Biblia Naturae*, p. 868.

[22] Robert P.W. Visser, "Theorie en praktijk van Swammerdams wetenschappelijke methode in zijn entomologie," *Tijdschrift voor de Geschiedenis der Geneeskunde, Natuurwetenschappen, Wiskunde en Techniek* 4, 1981, pp. 63-73, discusses this point at some depth.

[23] Swammerdam (n. 7), *Biblia Naturae*, pp. 868-869: "indien onse reeden valsch ende gebrekkelyk is, indiense niet door de ondervindingen kan ondersteunt werden, daar door beweesen werden, ende in de selve eyndigen, soo dunkt ons, dat'er geen sterker nogte krachtiger reedenen kunnen weesen; als dewelke uyt de ondervindingen ende de ervarentheeden selfs, daarse in moeten eyndigen, gehaalt werden. Synde alle andere reedenen, dewelke deese vaste ende onbeweeglyke grontvest niet en hebben, op hoe veel optellingen ende besluyten sy ook steunen, enigsints voor verdagt te houden; ende soo se met de ondervindingen niet overeen en koomen, geheel te verwerpen." This passage had originally been published in Swammerdam's *Bloedeloose Dierkens* (1669).

[24] Swammerdam (n. 7), *Biblia Naturae*, p. 870-871: "gelyk als we van alle saaken geen waaragtige ondervindingen kunnen verkrygen, ende alsoo geen klaar ende onderscheydentlyk begrip van deselve hebben (als van die, dewelke voor ons gesigt te kleen, ende van andere, dewelke daar te ver afgeleegen syn) soo moeten wy ook ons niet dwaselyk inbeelden, van oyt door onse reeden tot de waare ende eygentlyke kennis van de oorsaaken dier dingen, ik laat staan tot die van haare waaragtige uytwerkingen, te sullen koomen. Leggende ... onse aldergrootste Wysheid, niet in de kennis van de oorsaken der dingen, maar alleen in een net ende onderscheydentlyk begrip van derselver waare vertooningen, ofte haare uytwerkingen ... geleegen." This passage had originally been published in Swammerdam's *Bloedeloose Dierkens* (1669).

Swammerdam found the structure of matter inscrutable; indeed, "eye, hand, reason and instruments together are, because of its minuteness, too impotent'[25] to discover the finer details of its structure. Thus man's knowledge must of necessity remain limited, the ultimate causes of the phenomena stay hidden and can only be known to God. Therefore Swammerdam judged the accurate and detailed description of the nature as the highest goal of scientific enquiry.

These views on scientific method and knowledge appeared in the last chapter or epilogue of Swammerdam's *Bloedeloose Dierkens* of 1669. It is interesting to note that, in this chapter, Swammerdam implicitly dissociated himself from views he had advanced some years before in his doctoral thesis, entitled *De respiratione*, which had been published in 1667. In his thesis Swammerdam presented a series of brilliantly executed experiments and vivisections, with the object of proving that the air in respiration is not *attracted* into the lung as a result of a partial vacuum, but is rather *pushed* into it as a result of the expansion of the chest.[26] This point was of great importance since Swammerdam's objective was to reconcile the mechanism of respiration with the notion that all movement is caused by collision between particles, and has nothing to do with attractive powers.[27] These particular investigations were therefore designed to provide experimental evidence for a mechanical explanation of respiration, which was indeed thoroughly discussed by Swammerdam. As only two years later he rejected the possibility that man may arrive at sure knowledge about the causes of such processes, this attempt at causal explanation in *De respiratione* appears to constitute an anomaly within the total of his scientific output. This may be attributable to the influence of Swammerdam's associates in Leyden, and particularly to the scientific circle surrounding Franciscus dele Boë Sylvius, who was Swammerdam's intellectual mentor at Leyden University. A second series of physiological experiments, performed by Swammerdam at about the same time, appears to support such a view. Swammerdam demonstrated, by means of a nerve-muscle preparation of a frog's hind-leg, that the muscle, contrary to current belief, does not increase in volume during contraction.[28] These experiments were not published at that time, although they were known among his acquaintances, but only appeared in print half a century after his death in his *Biblia Naturae*. In his account of his experiments Swammerdam effectively destroyed the theory that the muscle contracts as the result of an influx of matter from the brain, but he did not produce an alternative explanation. Even so, from his researches on

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[25] Swammerdam (n. 7), *Biblia Naturae*, p. 503: "want oog, hant, verstant en instrumenten, syn daar al te saam om haar groote kleenheid te onvermogent toe."

[26] E.C. van Leersum, *Opuscula selecta Neerlandicorum de arte medica* 6, 1927, pp. vii-xv: "Ter Inleiding"; Gerrit A. Lindeboom, "Dog and frog. Physiological experiments at Leiden during the seventeenth century," in *Leiden university in the seventeenth century. An exchange of learning*, ed. Th. H. Lunsingh Scheurleer a.o. (Leiden: Brill, 1975), pp. 279-293, Winsor (n. 2), "Swammerdam, Jan."

[27] Jan Swammerdam, *Disputatio medica inauguralis, continens selectas de respiratione propositiones* (Leyden: Elsevier, 1667), paragraph 11 of chapter 1.

[28] Swammerdam (n. 7), *Biblia Naturae*, pp. 835-860; Nordström (n. 2), "Swammerdamiana"; Lindeboom (n. 25), "Dog and Frog."

respiration and muscle contraction it is apparent that during his formative years in the 1660s Swammerdam was involved with the contemporary shift in physiology from traditional explanatory notions towards a mechanical explanation of the various processes.

By the time his *Bloedeloose Dierkens* was published Swammerdam had come to despair of ever arriving at causal explanations and exclaimed,

> Oh God, Thy Works are inexplorable, and all we know, or can know of them, are nothing but the dead shadows of the shadows of shadows of Thy adorable and inexplorable works; for which all the minds of man, however ingenious they may be, must become dull and confess their ignorance.[29]

From then on he was content to point out "the rules and order, which the all-wise Creator has instilled unchangeably in the nature of things."[30] In fact, he considered that he had contributed substantially to science by discerning four different types of metamorphosis amongst the mass of observations on the development of numerous individual insects.[31] Nevertheless, on occasion Swammerdam suggested a mechanical explanation for the phenomena observed. For example, he attributed the hardening of the almost liquid parts of the butterfly within the body of the caterpillar to the evaporation of water.[32] Most of his suggestions, however, were equally insubstantial and therefore hardly suffice to represent him as a mechanicist.[33] With regard to Swammerdam's microscopical work this means that he made no attempt to solve any problems concerning the operation of living beings, as Hooke and Malpighi had tried to do. Having turned his mind and experimental skill towards the study of insects, Swammerdam set out to destroy the current notions concerning this group of animals, which he found to be completely mistaken. These notions are, firstly, that insects propagate through spontaneous generation; secondly, that in the course of their development they change suddenly from one form into another; and thirdly, that they lack any internal structure. The notion of spontaneous generation was categorically dismissed by Swammerdam in view of his belief in the uniformity of nature, which precluded chance,[34] and chance

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[29] Swammerdam (n. 7), *Biblia Naturae*, p. 664: "O GODT, uwe Werken syn ondoorsoekelijk, en alles dat wy daar van weten, of weten kunnen, syn niet als de doode schaduwen van de schaduwen der schaduwen uwer aanbiddelijke en ondoorsoekelijke werken; waar voor alle de verstanden der Menschen, hoe spitsvondig sy syn, moeten stomp worden, en haar domme onwetendheid bekennen."

[30] Swammerdam (n. 7), *Biblia Naturae*, p. 15: "de regelen ende orderen, van den alwysen Maaker, geheel onveranderlijk in den aard der saaken gestelt." This passage had originally been published in his *Bloedeloose Dierkens* (1669).

[31] Swammerdam (n. 7), *Biblia Naturae*, p. 4.

[32] Swammerdam (n. 7), *Biblia Naturae*, p. 37.

[33] As Schierbeek (n. 2), *Jan Swammerdam* and Winsor (n. 1), "Swammerdam, Jan" did.

[34] Visser (n. 22), "Theorie en praktijk"; Edward G. Ruestow, "Piety and the defense of natural order: Swammerdam on generation," in *Religion, Science, and Worldview. Essays in Honor of Richard Westfall*, ed. Margaret J. Osler and Paul Lawrence Farber (Cambridge: Cambridge University Press, 1985), pp. 217-241.

is exactly what may occur in spontaneous generation. A careful study of the development of a variety of insects, published in 1669 as *Historia insectorum generalis, ofte, Algemeene Verhandeling van de Bloedeloose Dierkens*, revealed the various types of metamorphosis and established beyond a shadow of doubt that this process was one of gradual change. Having settled this matter, Swammerdam turned towards the investigation of the anatomy of insects. It was an absorbing study, executed with great skill, but most of it was not published until half a century after his death, when Boerhaave published Swammerdam's manuscripts as *Biblia Naturae* in 1737 and 1738. It is this part of Swammerdam's researches that was to a large extent performed with the microscope. The results of his work were initially incorporated into separate treatises and letters to friends, such as Thévenot, although it was Swammerdam's intention to collect these into one volume.[35] The tracts and letters are not of an argumentative kind. On the contrary, they are purely descriptive, setting out in painstaking detail the life cycle and behaviour of the various animals, and the arrangement and function of their external and internal parts.

Microscopical science

Swammerdam did not often apply the microscope to the anatomy of the human and large vertebrate body. In his *Miraculum Naturae*, for instance, which deals with a subject that could benefit from the application of the microscope, i.e., the human ovary, he does not mention its use. Nor were other suitable subjects, such as the medulla spinalis, microscopically investigated. The research published by the *Collegium privatum* of Amsterdam[36] which primarily concerns larger vertebrates, especially fishes, is only infrequently augmented with microscopical details. There was one topic that he proposed to study experimentally with the microscope; this was the question of whether blood also contained the globules which had been observed in samples outside the body, as it coursed through the body. He proposed to insert a tube into a dog's vein, guide it past a microscopical apparatus, and lead the blood back into the body without ever exposing it to the air.[37] This experiment, which Swammerdam devised in 1678, was never actually performed.

In his *Bloedeloose Dierkens* Swammerdam mentioned the advantages offered by the microscope, but from the content of this book it appears that his close scrutiny of the insects did not involve the application of any optical instruments

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[35] Lindeboom (n. 4), *Letters of Swammerdam to Thévenot*; in his letters to Thévenot Swammerdam referred to his "great work," in which these various investigations were to be brought together.

[36] *Observationes anatomicae selectiores pars prima* (Amsterdam: Caspar Commelin, 1667) and *Observationum anatomicarum collegii privati Amstelodamensis pars altera* (Amsterdam: Caspar Commelin, 1673).

[37] Swammerdam (n. 7), *Biblia Naturae*, p. 69; Lindeboom (n. 3), *Letters of Swammerdam to Thévenot*, pp. 98-99; Gerrit A. Lindeboom, "Jan Swammerdam als microscopist," *Tijdschrift voor de Geschiedenis der Geneeskunde, Natuurwetenschappen, Wiskunde en Techniek* 4, 1981, pp. 87-110.

other than rather weak magnifying glasses. His *Ephemeri Vita* of 1675, however, and even more so the *Biblia Naturae*, abound with magnificent microscopical studies. It is therefore clear that Swammerdam only really concentrated on microscopical research from approximately 1670. However, he had acquired sufficient microscopical technique some years before to state, in his doctoral thesis, his views on the construction and operation of the organ of sight in insects.[38]

Swammerdam learnt from Johannes Hudde how to produce lenses for single microscopes some time in the 1660s.[39] These were the small globular blown lenses made from melted glass, a technique that was very simple, enabling Swammerdam to make over forty of these lenses, some bad, some good, in an hour.[40]

Swammerdam's greatest asset was his mastery of microscopical technique.[41] With great perseverance and ingenuity he endeavoured to dissect the minute bodies of some twenty different kinds of insects, among them a louse, bee, flea etc., in various stages of their development. To do so he used the conventional tools of the anatomist: knife, pincers, scissors (to which he was particularly partial) and needles, all of which were of course of delicate make. Some of the tools he acquired with considerable difficulty in France through Thévenot.[42] Over the years Swammerdam developed various techniques for improving contrast in his preparations, the lack of which he found to be one of the main obstacles in establishing the details of the insect anatomy.[43] He injected wax, tin or coloured liquids into the vessels, or simply used coloured glass for a background, but also applied colouring agents, dried his preparations, to mention but a few of the techniques to which he referred in his writings. Yet Swammerdam had probably mastered quite a few more besides. He once wrote proudly to Thévenot: "I have very many inventions in the field of microscopy, for otherwise it would have been impossible for me to discover what I could with it."[44] Moreover, he was well aware of the limitations and deceptions of lenses, however much he valued their powers. As to the deceptions Swammerdam

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[38] Swammerdam (n. 27), *Disputatio medica de respiratione*, Corollaria no's 22 and 23.

[39] Jan Swammerdam, *Historia generalis ofte algemeene verhandeling der bloedeloose dierkens*, (Utrecht: Van Dreunen, 1669), p. 81; Gerrit A. Lindeboom, "Zeer kleine glasbolletjes als sterk vergrotende mikroscoopjes gebruikt door Nederlanders in de tweede helft der zeventiende eeuw," in *Zusammenhang. Festschrift für Marielene Putscher* ed. Otto Baur & Otto Glandien, 2 vols. (Köln: Wienand Verlag, 1984), vol. 1, pp. 337-351, presumed that Swammerdam had learnt the technique from Van Leeuwenhoek, citing a passage to that effect from the *Biblia Naturae*, the afore mentioned paragraph in Swammerdam's *Bloedeloose Dierkens* having escaped him, apparently.

[40] Lindeboom (n. 4), *Letters of Swammerdam to Thévenot*, p. 138.

[41] Francis J. Cole, "Microscopic science in Holland in the seventeenth century," *Journal of the Queckett Microscopical Club* ser. 4, 1, 1938, pp. 1-20, Francis J. Cole, *A history of Comparative Anatomy. From Aristotle to the eighteenth century* (London: Macmillan, 1944), pp. 270-305; Pieter Smit, "Jan Swammerdam und seine Beobachtungen zur Metamorphose der Insekten," in *Hallesche Physiologie im Werden. Hallesches Symposium 1981*, ed. Wolfram Kaiser & Hans Hübner (Halle: Martin Luther Universität, 1981), pp. 35-43.

[42] Lindeboom (n. 4), *Letters of Swammerdam to Thévenot*, p. 63.

[43] Swammerdam (n. 7), *Biblia Naturae*, p. 405.

[44] Lindeboom (n. 4), *Letters of Swammerdam to Thévenot*, p. 102.

warned repeatedly that interpretation of the image should be carried out with care because it is not always easy to discern, for instance, between a hollow or spherical surface.[45] In his drawings, and perforce also in the published illustrations, Swammerdam chose not to depict all the details according to life, "because I think that too sorry an exertion and of little value,"[46] but preferred to depict the more important things as being slightly bigger than others.

The main emphasis of Swammerdam's microscopical research is on the anatomical structure of the insect body in its various developmental stages. Thus he noted the main features of insect anatomy, the general plan of insects' internal arrangement, experimenting at times with these parts so as to elucidate their operation. One instance of his thoroughness is provided by his experiments with the venom bladder in the bee and the adjoining stinging apparatus. He made the bees sting a wash-leather glove, and collected some of the venom to taste it in order to determine its nature.[47] Exploring the structure of the insect body Swammerdam could not but conclude that: "All the knowledge that we can have of the structure of these animals, we find to be placed nowhere else than in the sum of the parts, which we had observed before in larger animals."[48]

As an example of the care and finess of detail of Swammerdam's microscopical research, his dissection of the compound eye of the bee can be cited (figure 4). The eye of an insect, as he had already remarked in his doctoral thesis, has a reticulated outer surface. This is most easily observed when this surface, or horny layer, is separated from the rest of the eye and seen against the light. Subsequent research revealed the complex structure of the compound eye, beneath the outer layer,

> there are so many fibres as the horny layer of the eye on top has divisions: these fibres enclose quite nicely the bulging of the spherical divisions of the horny layer. Her form on top is six-cornered and wide, thinner in the middle and pointed at the end, moreover they are all of the same length, thickness, width and magnitude.[49]

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[45] Swammerdam (n. 7), *Biblia Naturae*, p. 491.

[46] Swammerdam (n. 8), *Ephemeri Vita*, p. 86: "want my dat een al te verdrietigen arbeyt docht te sijn; ende van weynigh nut."

[47] Swammerdam (n. 7), *Biblia Naturae*, p. 461.

[48] *Ibid.*, p. 2: "Ende alle de wetenschap, die wy van het maaksel deser Dierkens hebben konnen, bevinden wy niet anders gelegen te syn als in een optelling der deelen, dewelke wy te vooren in andere Dieren, die grooter waaren, beschout hebben." This passage had originally been published in his *Bloedeloose Dierkens* (1669).

[49] *Ibid.*, p. 493: "syn soo veel Vesels te sien, als het Hoornvlies en het Oog van bovenen verdeelingen heeft: deese Vesels sluyten heel net in de holligheeden van de spherische verdeelingen van het Hoornvlies. Haar figuur van boovenen is ses hoekig en breet, in 't midden dunder, en in 't eynde spits: voorts syn sy haast altemaal van eene langte, dikte, breette ende grootte."

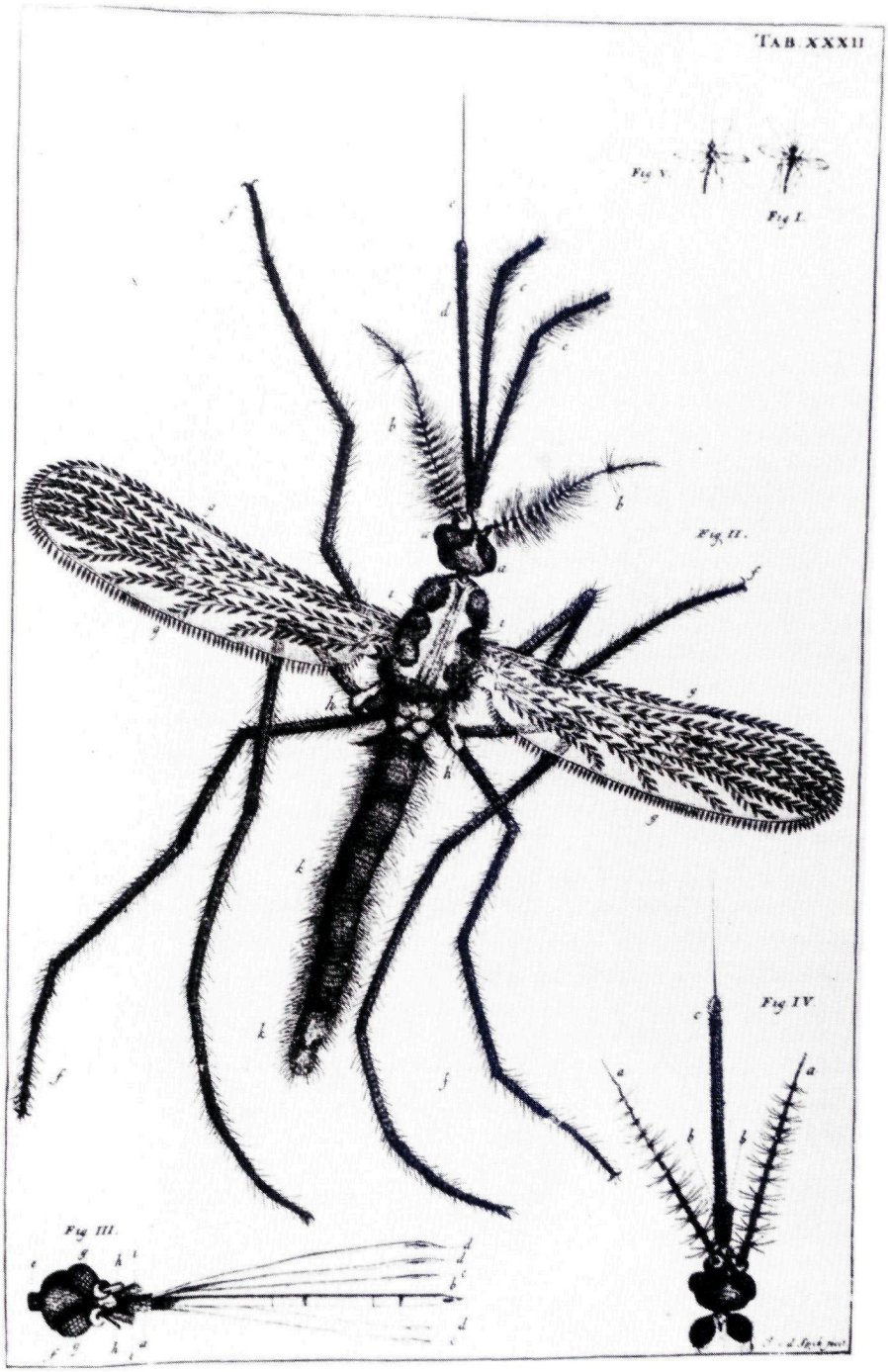

Figure 3 – Mosquito, Tab. XXXII from *Biblia Naturae.*

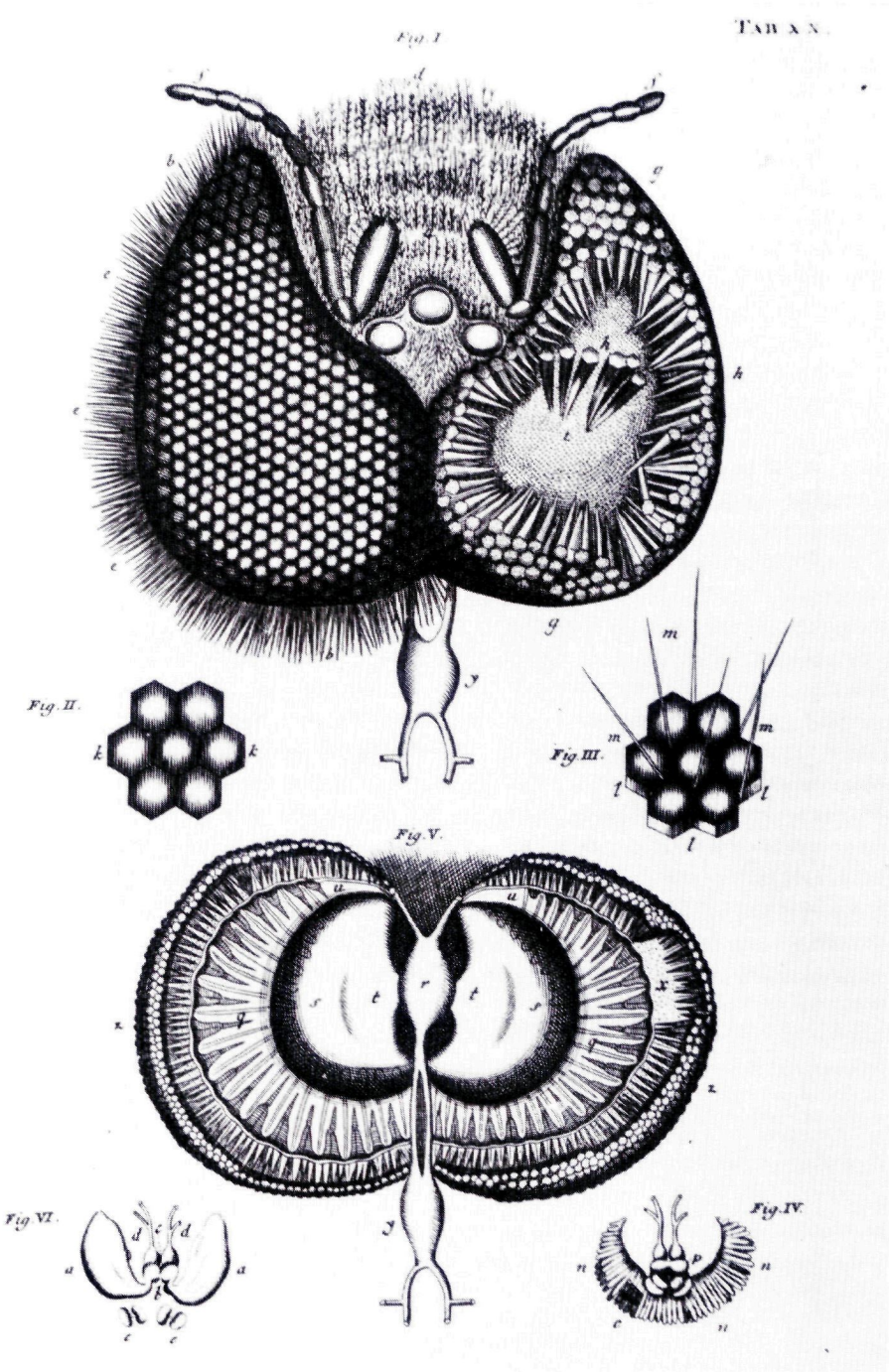

Figure 4 – Structure of the compound eye of the bee, Tab. XX from *Biblia Naturae.*

Between these pyramidical fibres he noted numerous air vessels and found that the points of the pyramids rested on a double-layered membrane, covering a brain-like substance. The outer surface of the membrane had a dented appearance caused by the imprint of the tops of the pyramids. The brain-like substance was described by Swammerdam as

> another or second kind of fibres, which are laid transversely against the undersurface of the described membranes, and appear as the foundation beams of the surmounted pyramidical fibres. These fibres differ from the upper pyramidical [ones] in that they are not so numerous as those and also by far not as delicate.[50]

Judging by their appearance these fibres constituted the cortex of the brain; this opinion was supported by the fact that Swammerdam, in contrast with Gioanbatista Odierna, who had dissected the fly's eye some thirty years earlier,[51] observed a link between this substance and the brain proper.

Swammerdam saw that the bases of the pyramids contained a coloured substance. This substance usually came away together with the horny layer when this was separated from the rest of the eyes. Swammerdam identified this substance with the retina. Therefore, according to Swammerdam, the retina of the insect eye was located directly beneath the horny layer. Swammerdam's ideas concerning the operation of the compound eye are shaped by this proposition. He wrote, "these eyes are thus constructed in such a way that they receive the images of things by a single propulsion of the reflected light."[52] In *Ephemeri Vita*, Swammerdam had elaborated this idea somewhat, writing

> The vision of these animals [insects] operates in a quite different manner to that in us, where it comes about through a gathering of rays within the eye. In these it comes about by a gathering of nervous fibres, which, at the moment of seeing, are but shortly touched and moved on their bulging by the visible qualities and the rays of light and colour.[53]

Swammerdam therefore thought that images were formed directly beneath the outer surface of the compound eye, and that a multitude of images were separately relayed through the fibres to the brain. Although Swammerdam's description of the

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[50] Swammerdam (n. 7), *Biblia Naturae*, p. 495: "een ander of tweede soort van Vesels ... dewelke tegens de beschreeve Vliesen van onderen dwars aangelegt syn, ende als de fondament balken van de boven op staande pyramidale Vesels haar vertoonen. Deese Vesels verscheelen van de bovenste pyramidale, dat se in soo groote kwantiteyt niet en syn als deselve, ende ook op ver na soo subtiel niet."

[51] Gioanbatista Odierna, *L'Occhio della mosca* (Palermo: Cirillo, 1644).

[52] Swammerdam (n. 7), *Biblia Naturae*, p. 501: "Soo syn dan deese Oogen soo gestelt, dat se de gedaantens der dingen, door een enkele voortstooting van het weeromgekaatste ligt, kunnen ontfangen."

[53] Swammerdam (n. 8), *Ephemeri Vita*, p. 120: "Soo dat het gesight van deese beeskens, op een heel andere wijse, als in ons toegaat. Alwaar het door een vergaderingh van straalen, binnen in het oogh geschiet. Daar het selve alhier, door middel van een vergaderingh van senuachtige draatkens, toegaat; en die op de tijt als sy sien, maar eeven op haare verheventheeden, door de sienelycke hoedanigheeden en straalen van licht ende couleur geroert en beweeght worden."

construction of the compound eye was by far the most detailed of any of his contemporaries, his explanation of the operation of this eye is rather unsatisfactory, particularly so in the light of the very lucid account of the optical properties of the compound eye presented by Robert Hooke in his *Micrographia*,[54] which Swammerdam knew well. However, he criticised Hooke on account of the latter's reference to a fluid within the eye which, as Swammerdam wrote somewhat accusingly, Hooke needed to explain the operation of sight, but which in Swammerdam's experience did not exist.

Swammerdam's research on insects was concerned with their development, appearance, anatomy and way of life. Of their internal parts, Swammerdam described minutely the details of the alimentary duct, the respiratory, circulatory and nervous systems, as well as the generative organs. In so doing he was guided by the general plan of the vertebrate body. For instance, having localized the stomach he could work out the various other parts of the alimentary duct, keeping in mind the succession of parts in the vertebrate body. Moreover, he was conversant with the data of contemporary investigators, particularly those of Hooke and Malpighi, both of whom he praised highly.[55]

Conception of nature

Swammerdam's conception of nature was based on rigorous order, a concept that precluded chance and corresponded with uniformity.[56] Consequently, he rejected both the notion of spontaneous generation and the contemporary view of the metamorphosis of insects as a process of sudden change from one image into another. His exposure of the future butterfly, which lies hidden in a completely finished form beneath the skin of the caterpillar, was a most convincing demonstration with respect to his theory of metamorphosis. Even better perhaps, this demonstration may in the first place have been decisive in the formation of his ideas on this topic. It is certain that Swammerdam performed this feat in 1668,[57] but probably even earlier, in 1662.[58] In essence, Swammerdam stated that although the insect changed successively from one form into another it remained the same individual throughout the process. The various parts, which are present in the imago but not in the caterpillar, do not appear suddenly but "grow on slowly, one

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[54] Robert Hooke, *Micrographia: or some physiological descriptions of minute bodies made by magnifying glasses* ... (London: J. Martyn, 1665), pp. 175-180.

[55] Swammerdam (n. 7), *Biblia Naturae*, for instance about Hooke (p. 501) and about Malpighi (p. 410).

[56] Peter J. Bowler, "Preformation and pre-existence in the seventeenth century: a brief analysis," *Journal of the History of Biology* 4, 1971, pp. 221-244; Ruestow (n. 34), "Piety and defense of natural order."

[57] Lindeboom (n. 4), "Introduction," p. 13.

[58] Borch (n. 3), *Itinerarium*, p. 241; Nordström (n. 2), "Swammerdamiana."

part after the other ... and they are increased and born in this swelling, budding forth, rising up, budding and as if stretching of new limbs, gradually by an addition of parts."[59]

Swammerdam's insistence that the insect had already acquired its form in previous stages and that the egg is "the animal itself," coupled to a reference concerning the pre-existence of man as far back as the ovaries of Eve and some similar remarks,[60] has caused a number of historians of science to call him a preformationist.[61] As Swammerdam had managed to see some, albeit very fluid, structure already present in the egg, and had concluded that the future individual had acquired its form at that stage,[62] such a designation was obvious, but on further consideration misconceived.

The rise of the concept of preformation and its counterpart, pre-existence,[63] is definitely coupled to the introduction of the mechanical philosophy in the life sciences. As preformation entailed the growth of preformed structure through the incorporation of additional matter, it offered a feasible explanation of ontogenesis, but the mechanical philosophy as a motive is certainly not applicable to Swammerdam's notions concerning pre-existence. Recent scholarship has demonstrated that Swammerdam's remarks on this topic ought to be evaluated in the light of his emphasis on order and regularity in nature. It is argued[64] that Swammerdam's conception of "invisible but essential principles," from which the future individual develops, and which forestalled the direct intervention of God in generation, stemmed from a concern to maintain predetermined order in nature. Certainly, Swammerdam's rare remarks on the developmental process are ambiguous and obscure. His main point with respect to generation was that "there is absolutely no generation in the whole of nature, and not as generation, or growing of parts."[65] This view implied that development was effected through growth of pre-existent parts. And indeed Swammerdam envisaged development initially as epigenesis, which included the growth, swelling and budding of existing parts. As a result of subsequent research, epigenesis came to include the addition of novel parts and the loss and the rearrangement of parts. His investigations into a kind of fly called Asy-

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[59] Quoted from Winsor (n. 2), "Swammerdam, Jan," from Swammerdam's *Biblia Naturae* (1737-1738).

[60] Swammerdam (n. 7), *Biblia Naturae*, p. 34. This passage had originally been published in his *Bloedeloose Dierkens* (1669).

[61] Francis J. Cole, *Early theories of sexual generation* (Oxford: Clarendon Press, 1930), pp. 41-44; Joseph Needham, *A history of embryology* (Cambridge, Cambridge University Press, 1934), pp. 148-149; Jacques Roger, *Les sciences de la vie dans la penseé Française de 18e siècle* ... (Paris, Armand Collin, 1971), pp. 334-335.

[62] Swammerdam (n. 7), *Biblia Naturae*, p. 728.

[63] Bowler (n. 56), "Preformation and pre-existence" discusses the distinction between the two.

[64] Ruestow (n. 34), "Piety and the defense of natural order."

[65] Quoted from Bowler (n. 56), "Preformation and pre-existence," note 41, from Swammerdam's *Bloedeloose Dierkens* (1669).

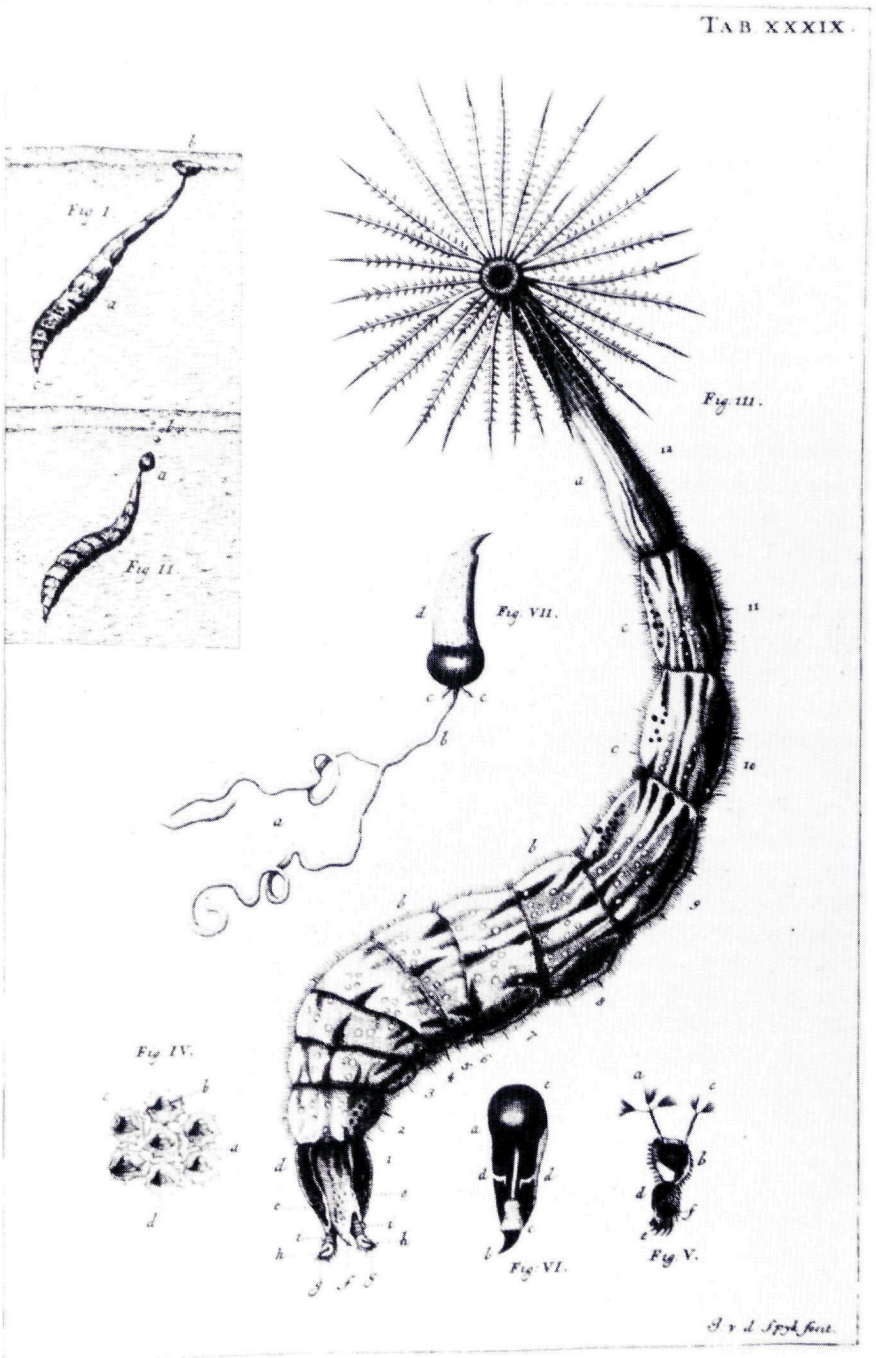

Figure 5 – Larva of *Asylus*, Tab. XXXIX from *Biblia Naturae*.

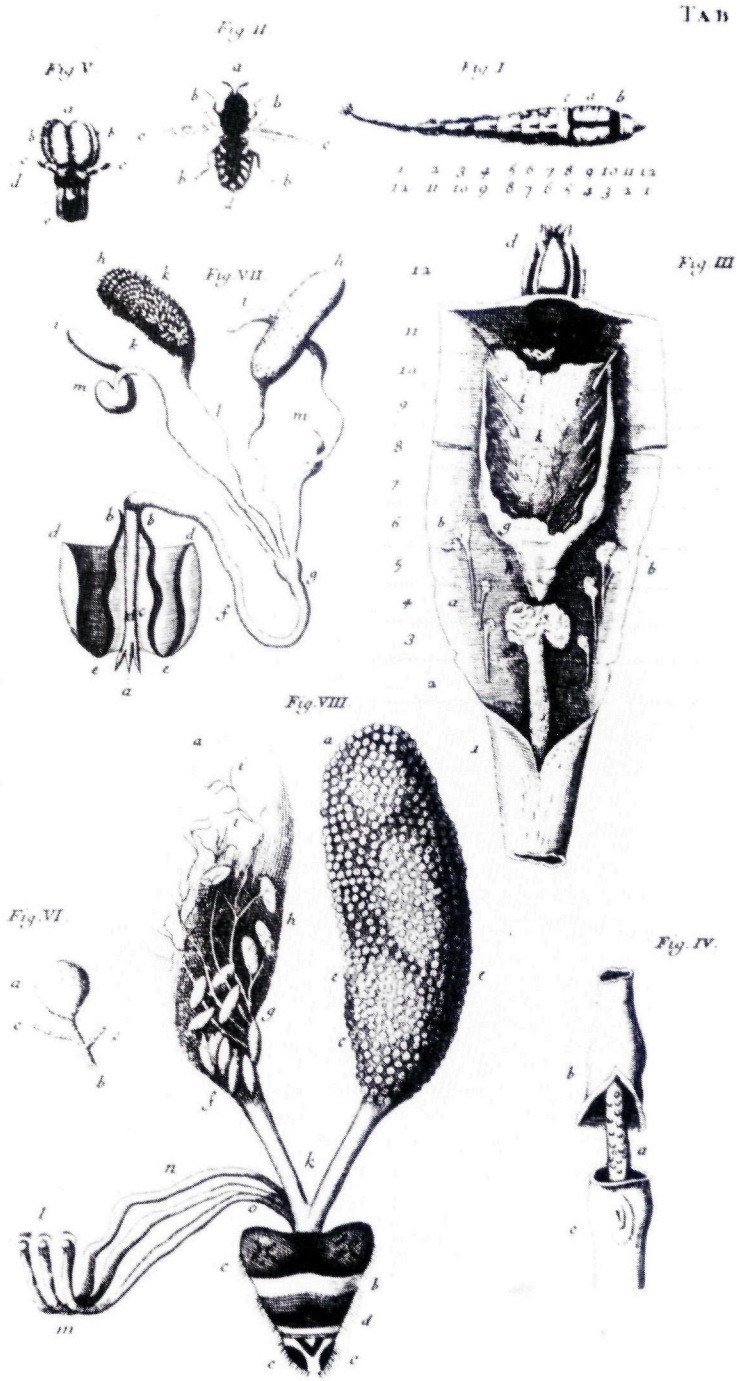

Figure 6 – Anatomy of the adult *Asylus*, Tab. XLII from *Biblia Naturae*.

lus (see figures 5 and 6), carried out in November 1677 had disclosed some puzzling facts, namely that the arrangement of the nervous system changed considerably, and that the gut of the larva disappeared while a new gut is formed in the imago. Swammerdam exclaimed in wonder "it may be considered as a putting aside of the old parts, a new creation or a resurrection of the old body in a new."[66] Swammerdam did not therefore imagine that a miniature of the adult animal was contained within the egg. He fully realized that the embryo differed considerably in appearance as compared to the adult, not only in insects, but in higher animals as well. With respect to the development of the tadpole on the second day he wrote "I only saw the globules earlier described, from which that animal seems to take its origin, from a collection of globules curdled together."[67]

Swammerdam was in fact concerned with visible things, and his remarks on the invisible origins of the embryo may be regarded as loose speculations, fitting in nicely with some biblical problems,[68] or, alternatively, as rather ill-considered elaborations on the order prevailing in nature.[69] In neither case did he envisage a fully formed embryo within the egg, as contemporaries and eighteenth-century scholars proposed, but rather a scenario for the individual's future development, imprinted on the matter within the egg.

Order in nature, as perceived by Swammerdam, covered the unchanging sequence of stages in metamorphosis, the regular patterns in the life cycles of insects and their behaviour, the similarity in the anatomy of all animals, including insects, the regular matching between a specific host and a specific parasite, and so on. With respect to the uniform master plan of animal anatomy he wrote "one can state with truth that God has created only one animal, which he has concealed and made distinct underneath an infinity of shapes, curves, convolutions, and stretchings of limbs: to which he has subjoined a different nature, way of life, and food."[70] This explicit statement concerning God's master plan obviously issued from the pen of an experienced anatomist struck by the similarities he had observed in the anatomies of a wide range of animals, whereas the statements concerning pre-existence usually quoted from Swammerdam's writings were made by a man struggling with religious dogma.

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[66] Swammerdam (n. 7), *Biblia Naturae*, p. 666: "en als voor een aflegging van de oude deelen, een nieuwe schepping, of een opstanding van het oude lichaam in een nieuw te agten is."

[67] *Ibid.*, p. 815: "alleen sag ik de voorige beschreeve greinkens, uyt welke dat Dier syn begintsel schynt te neemen, uyt een versameling van te samen en aan een gestremde klootkens."

[68] As advocated by Bowler (n. 56), "Preformation and pre-existence."

[69] As advocated by Ruestow (n. 34), "Piety and the defense of natural order."

[70] Swammerdam (n. 7), *Biblia Naturae*, p. 713: "men met waarheid kan seggen, dat GODT maar een eenig Dier geformeert heeft, en dat onder oneyndige gestalten, buygingen, samen windingen en uytrekkingen van leedemaaten verborgen, en onderscheyden heeft: waar by hy dit selve een verschilligen aart, manier van leeven, en voetsel heeft toe geschikt."

Conclusion

In his *Biblia Naturae* Swammerdam described the details of the appearance, development and the anatomy of insects in a truly breathtaking way. From an examination of its contents it appears that throughout the preparation of this impressive work he kept strictly to the rule that observation and experiment must form the basis for subsequent theorizing. In Swammerdam's view the object of scientific enquiry was to explore the details of God's creation and to study and describe the phenomena of nature, whether they be the movements of the stars or the anatomy of a louse. With the latter object in view the microscope served as a indispensable tool with which to resolve the finest details of the anatomy of insects and other minute creatures.

The exacting attitude to scientific investigation which induced Swammerdam to concentrate on meticulous description was strengthened during the mid-1660s, when he worked more or less simultaneously on the problems of respiration in vertebrates and the metamorphosis of insects. In keeping with the tenets of empirical science he tackled the problem of respiration by means of a series of experiments. The explanations he subsequently advanced were steered to fit in with the prevailing mechanistic explanatory framework. However, Swammerdam realized that mechanistic explanations for physiological processes, such as his own explanation for respiration, were inadequate and artificial, particularly so since at the same time he had come to see, in the course of his entomological investigations, that careful observation led to new and original results, results which he deemed important and of which he was proud.

From numerous statements in Swammerdam's *Biblia Naturae* it is apparent that the main motivation for his microscopical study of insect anatomy stemmed from his deeply felt admiration for God's magnificence. In his view God's guiding hand was nowhere more manifest than in the orderly and intricate arrangement of processes and structures in organic nature. The observation of the delicate and exquisite fabrics of living beings, revealed when he began to use a microscope to explore the anatomy of insects, could only support his original point of view. Moreover, by the time that Swammerdam was able to complete his studies on insects (the second half of the 1670's) he had resolved the earlier conflict between traditional forms of worship and his passionate commitment to science. By that time he regarded the description of nature as a form of worship.

Summary

Jan Swammerdam's name is firmly linked with the first successes in microscopical research. Whereas most of the early microscopists were preoccupied with the animal 'oeconomy', Swammerdam's microscopical investigations are of a purely descriptive nature. In the present study it is argued that this choice reflects Swammerdam's view that it is impossible to arrive at certain knowledge of the ultimate causes of the natural phenomena. In his view therefore the object of scientific enquiry was to explore the details of God's creation and to study and describe the phenomena of nature, whether they be the movements of the stars or the anatomy of a louse. With the latter object in view the microscope served as an indispensable tool with which to resolve the finest details of the anatomy of insects and other minute creatures.

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