Reading and writing *The Book of Nature*: Jan Swammerdam (1637–1680)

Matthew Cobb

Jan Swammerdam, a 17th-century Dutch microscopist, made major discoveries in medicine and anatomy. However, his greatest contribution to biology was his understanding of insect development and his demonstration that the same organism persists through its various stages. Using meticulous dissections and careful experimentation, he showed the errors of spontaneous generation and laid the basis of the modern understanding of morphogenesis. His science was profoundly marked by his mystical religious convictions, which often entered into contradiction with his avowed 'experimental philosophy' and even led him to abandon science for a period. This mystical aspect has often led to his work being misunderstood.

Something happened to European science in the 17th century. Major paradigm shifts took place in physics, mathematics and astronomy, that were underpinned by the adoption of a systematic experimental methodology and inspired by the work of Bacon, in particular. But nothing similar happened in 17th-century biology[1]. Despite major advances, there was no revolution in knowledge equivalent to that of the Galilean or Newtonian revolutions in the physical sciences. That event had to wait until the middle of the 19th century: biology's first Newton was Darwin.

Yet, although there was no specifically biological 'revolution', a qualitative change did take place in this period, as a consequence of two key epistemological innovations. First, natural history increasingly adopted Bacon's reliance on experimentation. Second, the invention of the microscope in Holland in the early years of the century had a massive impact on the perception of the natural world – both literally and figuratively.

The role of the microscope in 17th century science and the interaction between theoretical, social and technological developments in the history of science have recently been the subject of major studies by Catherine Wilson[2], Marian Fournier[3] and Edward Ruestow[4], which have contributed to the scientific rehabilitation of one of the key figures in the history of biology, the Dutch microscopist Jan Swammerdam (1637–1680; see Figure 1).

Matthew Cobb

Is a behavioural geneticist who studies chemical communication in flies and ants at the Laboratoire d'Ecologie, CNRS-Université Paris 6, Paris, France. He is also the translator of a number of books, including *A History of Molecular Biology* and *Darwinism's Struggle for Survival*. He is currently working on a scientific biography of Jan Swammerdam.
mcobb@hall.snv.jussieu.fr

Swammerdam's studies

Trained as a doctor in the prestigious new university of Leiden, Swammerdam was one of a group of highly talented students that included de Graaf (1641–1673), Stenson (1638–1686) and Ruysch (1638–1728), each of whom made major contributions to science. Among his many anatomical and medical discoveries, Swammerdam found that muscles do not expand when contracted, that eggs are present in the human ovary, that there are valves in lymphatic vessels and that penile erection is due to an influx of blood. He also carried out a series of brilliant physiological studies of respiration, pioneered the frog nerve–muscle preparation, was one of the first to observe red blood cells, developed a novel method for preserving anatomical specimens involving the injection of hot wax, described the anatomy of the uterus and discovered the nature of hernias[6].

Even if this was the sum total of his life's work, Swammerdam would clearly merit a place in the history of anatomy and medicine. However, in the 1670s, his work went far beyond these rather unfocused findings and took biology as a whole onto a new plane.

Swammerdam's work on insects

From childhood, Swammerdam was passionately interested in insects, to the continued annoyance of his father, an apothecary who hoped that Jan would practice medicine (he never did) and earn himself a living (ditto)[6]. In the late 1660s, Swammerdam began to dissect insects – he was the first to realise that the 'king' bee was in fact a queen, when he discovered her ovaries. Then, perhaps prompted by Hooke's *Micrographia* (1665), he started to use the microscope to observe the behaviour and structure of insects (Box 1).

It was in 1669 that Swammerdam realised he could combine his anatomical skills and the microscope. His friend and patron, the French diplomat and man of letters Melchisedec Thévenot (1620?–1692), sent him a copy of Malpighi's recently published monograph *De Bombyce*

0160-9327/00/$ – see front matter PII: S0160-9327(00)01306-5

Figure 1 This is not Jan Swammerdam. No known portrait of Swammerdam exists. However, this alleged portrait of him still resurfaces occasionally. There are at least three versions in existence, the first two are mid-19th century lithographs taken from a painting, sometimes attributed to Rembrandt. (a) The lithograph reproduced here was made by Berghaus in 1851, allegedly from a drawing by Jan Stolker (1724–1785) taken from a painting by Rembrandt (a similar lithograph was made by Lankhaut). (© Netherlands Institute for Art History. Reproduced with permission.) (b) A more stylised woodcut was made by Giacomelli to accompany the 1875 edition of Jules Michelet's *L'Insecte* (© Bibliothèque centrale MNHN, Paris. Reproduced with permission). Could the portrait be genuine? Swammerdam and Rembrandt lived in Amsterdam at the same time and, according to one far-fetched story, Swammerdam treated the artist's son, Titus when he was ill. The truth is complicated: Rembrandt both is and is not the author of this 'portrait' of Swammerdam. He is *not* the author because the portrait allegedly shows Swammerdam with a copy of his book on the may-fly, *Ephemeri vita*. The book was published in 1675, whereas Rembrandt died in 1669. In a way, however, he is the author, because the face in the portrait of Swammerdam has been taken from (c) Rembrandt's masterpiece 'The Anatomy Lesson of Dr Tulp' (Detail. © Mauritshuis, The Hague). Nicolas Tulp was head of the Leiden medical school where Swammerdam studied. Although they did know each other, Tulp retired from teaching before Swammerdam arrived, so it is unlikely that Swammerdam actually assisted at one of his dissections. More decisively, the painting was done in 1632, five years before Swammerdam was born. The face has been identified as that of Hartmann Hartmanzoon (1591–1659). It seems most likely that the original 'portrait', the whereabouts of which are unknown, was concocted – not necessarily with malicious intent – by Jan Stolker, who apparently had a 'talent for creating new compositions with elements taken from older models'[5].

(1669), a pioneering account of the micro-dissection of the silk-worm larva[7]. This magnificent work clearly inspired Swammerdam, and throughout the 1670s, despite repeated attacks of malaria, he made a series of dissections of insects, demonstrating that they contained complex internal organs, thus breaking with two millennia of Aristotelian tradition. These studies were finally summarised in his magisterial *Book of Nature* (see Box 2). Figure I, Box 2 shows the scale of Swammerdam's innovation, comparing his 1675 drawing of a male may-fly nymph (*Palingenia longicauda*) with Dortman's drawing, published in 1634 by Augerius Clutius[8].

Despite the many discoveries he made in insect anatomy and natural history, Swammerdam's most important – and most misunderstood – contribution was to the study of development. He asserted two fundamental truths: first, that there is no such thing as spontaneous generation; and second that the various stages in the insect life-cycle – egg, larva, pupa and adult – merely represent different forms of the same individual. At the time, these two positions were closely linked; thus Swammerdam argued in *The Book of Nature* that his work 'eradicates entirely the false notion of metamorphosis or change of one creature into another, that universal chimera of erring opinions, and totally destroys and subverts the monstrous opinion of a fortuitous generation of creatures'.

From his 1669 work *Historia Insectorum Generalis* onwards, Swammerdam sought to integrate his observations into a general classification of insects by discovering the 'rules and theorems' of morphogenesis – an ambitious project, even today.

He identified four 'orders' of 'insects' (the definition of the time was much looser than today) corresponding to different developmental pathways. The first, and simplest, is a diverse groups of creatures such as spiders, scorpions, snails and ametabolous insects (such as lice) where the adult form hatches directly out of the egg. In the second order (which includes dragonflies, locusts and the may-fly), a nymph hatches out of the egg and then gradually develops into the adult form. The third and fourth orders – holometabolous insects with a pupal stage, such as butterflies, bees or flies – are those that posed the greatest intellectual challenge at the time, and still remain poorly understood today.

Many writers have argued that in carrying out this pioneering and ambitious study, Swammerdam founded 'preformationism' and 'emboîtement' – the idea that all subsequent generations are present in any given individual, stacked up like so many Russian dolls – and that this was profoundly linked to his religious convictions. For example, one historian has written: 'Swammerdam developed an extreme form of the preformation theory, supposing that an egg contained all the future generations of its kind as preformed miniatures, like a series of boxes one inside the other. "In nature there is no generation," wrote Swammerdam, "but only propagation, the growth of parts. Thus original sin is explained, for all men were contained in the organs of Adam and Eve."'[9]

This widely held view is based principally on Swammerdam's study of butterfly metamorphosis, where the adult structures – wings, legs, antennae, etc. – gradually appear within the caterpillar prior to pupation. As early as

BOX 1 SWAMMERDAM'S TECHNIQUES

Like most 17th century microscopists, Swammerdam favoured single-lens microscopes. The compound microscope only came into its own in the mid-18th century when optics had improved. None of Swammerdam's microscopes have survived, but we know that he used small bead-lenses (1–2 mm in diameter), some of which he made himself, and which probably had a maximum magnification of around 150 × (Ref. a).

In March 1678, Swammerdam sent a blood sample to Thévenot with a drawing of a microscope (Fig. Ia) that bears a striking resemblance to the microscopes made at the time by Musschenbroek in Leiden. Figure Ib shows a copy of the drawing and an interpretation of the microscope in use (Fig. Ic). It seems probable that Swammerdam used this kind of device.

The single-lens microscope is, effectively, a very small magnifying glass: the object almost touches the lens and the observer has to place their eye close to the lens in order to see the object, and even then it is often difficult to discern anything much, as Samuel Pepys disappointedly observed[b]. Swammerdam warned the readers of *The Book of Nature* that the lens 'must, for this purpose, be carefully managed, for as it is turned one way or another, different things are seen: one cannot bring the lens nearer, or remove it further, by the least distance, but something is immediately perceived by the sight, which was not observed before'.

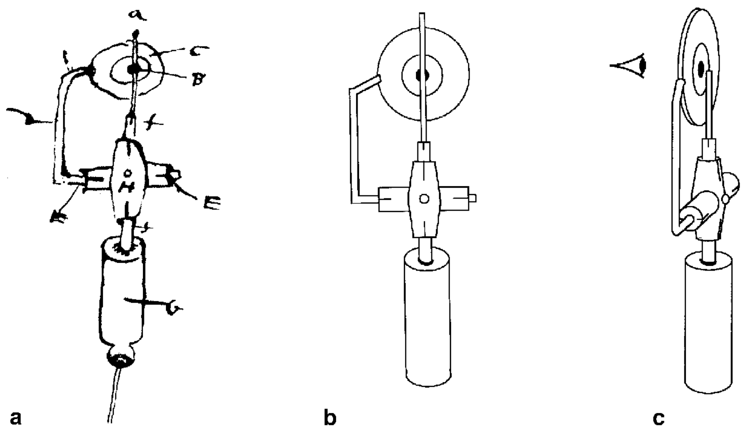
In *The Book of Nature*, Swammerdam states that he only observed under direct natural light, generally outside on summer mornings, bare-headed to allow the maximum amount of light to reach the lens, 'with the sweat pouring down my face', then writing up his results at night. In a number of letters he explains that he stopped his observations in the autumn and winter, for want of light.

His astonishing dissections were carried out with a variety of tools – fine pairs of scissors, a saw made from a small piece of watch spring, a fine sharp-pointed pen-knife, feathers, glass tubes, small tweezers, needles and forceps – and using a number of original and highly effective techniques to clean the samples, dissolve unwanted tissues and highlight those of interest. In particular, he developed a method for blowing air down fine glass tubes in order to inflate vessels or to remove tissues, which is still used in developmental biology laboratories.

Swammerdam apparently made most, if not all, his drawings himself, first in red ink, then completed in black ink or pencil[c] (unlike his great contemporary Antoni van Leeuwenhoek, who employed a number of non-scientific draughtsman). Swammerdam recognised that parts of some drawings were not drawn to scale, but, as he wrote in *The Book of Nature*:

> Neither need I be uneasy if I have delineated one part somewhat longer, and the other somewhat less; the microscope not admitting of greater accuracy.

The drawings were then copied onto copper plates for printing, a process that Swammerdam, like many contemporary authors[d], found particularly frustrating; in many of his letters he complains about the cost, accuracy and efficiency of engravers.



a **b** **c**

Figure I Swammerdam's microscope. (a) Swammerdam's drawing of a microscope used for looking at a blood sample, from his letter to Thévenot, 30 March 1678 (© Swetz & Zeitlinger, reproduced with permission). His original caption reads:

One uses it here in this manner (a) the glass tube full of blood, (B) the microscope lens set in ebony (C), a little flexible copper clasp (D) set into the wood of the microscope and that moves EE; a copper tube (ff) that moves to and fro and is fixed on a turned piece of ebony, G. Another little piece of copper H moves to and fro on the copper tube; the copper EE has been rivetted on it and turns around.

It is not clear what the two lines descending from the ebony handle are supposed to represent. (b) Redrawing of Swammerdam's original. (c) Interpretation of the microscope in use. The glass tube has been replaced by an object holder.

Notes and references

a Fournier, M. (1996) *The Fabric of Life: Microscopy in the Seventeenth Century*, Johns Hopkins University Press
b Jardine, L. (1999) *Ingenious Pursuits: Building the Scientific Revolution*, p. 43, Little, Brown and Company
c Cole, F.J. (1944) *A History of Comparative Anatomy*, Macmillan
d Johns, A. (1998) *The Nature of the Book: Print and Knowledge in the Making*, p. 435, Chicago University Press

1667, in front of a meeting of Thévenot's circle (a predecessor of the French Académie des Sciences), he dissected out these adult structures, showing 'a Butterfly enclosed and hidden in a caterpillar, and perfectly contained within its skin' as he put it, much to the amazement of his audience. However, as he admitted in *The Book of Nature*, these structures are partial, extremely fragile and can only be seen in caterpillars that are close to pupation.

Swammerdam did not argue that the whole adult butterfly was literally present under the caterpillar's cuticle (he was far too skilled an observer to make such a mistake). His objective was simply to demonstrate what today seems obvious: the same individual is present in all stages of the insect life cycle.

The proof that he had no conception of 'emboîtement' is shown by his study of the 'fourth order' (mainly flies), where metamorphosis involves the virtually complete dissolution of the larval structures and, unlike the butterfly, no adult structures can be seen prior to pupation[10]. Far from arguing that the forms of the adult fly are present within larva, Swammerdam describes the massive changes that occur in the nervous and digestive systems and the muscles of the larva during pupation. On the basis of a series of dissections at different stages in development, he rightly insists that there is no 'metamorphosis' in the sense of one individual changing into another, but rather that the same individual undergoes 'astonishing transformations' and 'disagreeing transmutations'.

BOX 2 *THE BOOK OF NATURE*: 60 YEARS IN PRESS

No sooner had Swammerdam left the Bourignon cult in 1676 than he began to plan his 'great work' – a book based on his analysis of development contained in the *Historia Insectorum Generalis* (1669), but including all his subsequent discoveries on insect development and anatomy, in particular his long-promised *Treatise on Bees* (around 70,000 words).

From 1676 until his death he worked incessantly, rewriting his previously published material and carrying out new research. For example, he extended the material on ants from half a page in the *Historia Insectorum Generalis* to over 12 pages in *The Book of Nature*. He also wrote a series of scientific letters to Thévenot, subsequently included as whole new sections, such as his astonishing description of the behaviour, anatomy and metamorphosis of the cheese skipper fly and its larva (Figure 2).

By the end of 1679, the manuscript was complete and the illustrations were virtually finished; two plates had been cut and the translation from Dutch to Latin was underway. However, Swammerdam's health took a turn for the worse as his malaria returned. After a final debilitating fever, he died on 17 February 1680, leaving his papers and 52 copper plates to his great friend Thévenot, with the request that he publish them.

Thévenot was not able to meet Swammerdam's dying wishes. Initially, the translator refused to release the manuscript. After a two-year lawsuit, Thévenot eventually acquired the papers but he died before he could prepare them for the press. Thévenot's papers were then sold and the manuscript bought by the King's painter, Joubert. On Joubert's death it was sold again. The great Dutch physician Herman Boerhaave (1668–1738) eventually learned of the existence of the papers and managed to buy them in 1727, just as a swindler was trying to pass them off as his own[a].


BYBEL DER NATUURE,
DOOR
JAN SWAMMERDAM,
AMSTELDAMMER.
OF
HISTORIE DER INSECTEN,
TOT ZEEKERE ZOORTEN GEBRACHT. DOOR VOORBEELDEN, ONTLEEDKUNDIGE ONDERZOEKINGEN VAN VEELERHANDE KLEINE GEDIERTENS, ALS OOK DOOR KUNSTIGE KOPERE PLAATEN OPGEHELDERT.
VERRYKT MET ONTELBAARE WAARNEMINGEN VAN NOOIT ONTDEKTE ZELDZAAMHEDEN IN DE NATUUR.
Alles in de Hollandsche, des Auteurs Moedertaale, beschreven.
HIER BY KOMT EEN VOORREEDEN, WAAR IN HET LEVEN VAN DEN AUTEUR BESCHREVEN IS DOOR
HERMAN BOERHAAVE,
PROFESSOR IN DE MEDICYNE &c. &c.
DE LATYNSCHE OVERZETTING HEEFT BEZORGT
HIERONIMUS DAVID GAUBIUS.
PROFESSOR IN DE MEDICYNE EN CHEMIE.
II. DEELEN.

TE LEYDEN,
By ISAAK SEVERINUS, BOUDEWYN VANDER AA, PIETER VANDER AA.
MDCCXXXVII.

Figure II The frontispiece of *Bybel der Natuure* (1737).

Like Thévenot, Boerhaave found that preparing the papers for publication was more difficult than at first appeared. He had to reduce the section on the may-fly by cutting 'all the pious meditations and religious sentiments with which the original is so liberally furnished'[b]. This meant cutting nearly 80% of Swammerdam's writings on the may-fly. He also had to track down some missing material from the treatise on bees and decide where to insert the scientific letters to Thévenot. Finally, he had an extra plate cut, depicting the sporangia of ferns.

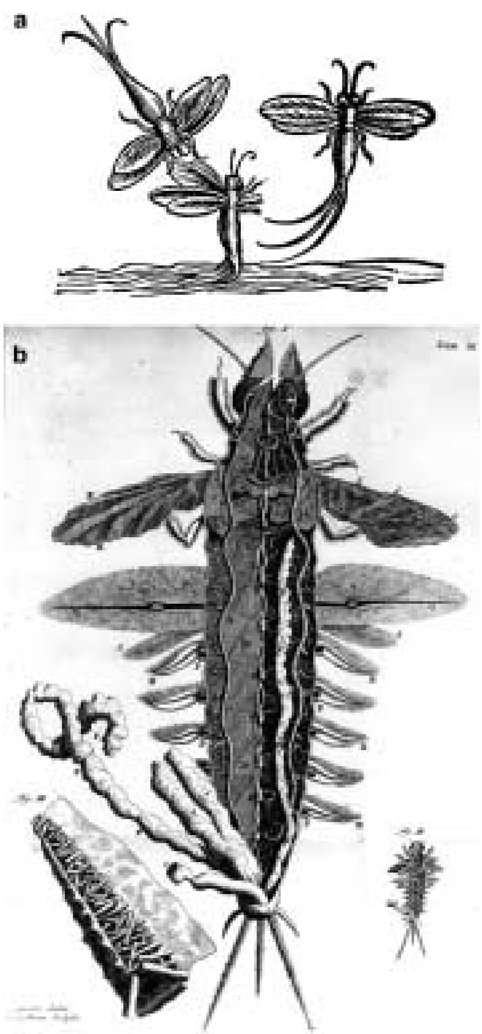


Figure I May-flies (*Palingenia longicauda*). (a) Dortman's drawing published in 1634 by Augerius Clutius in *De Homeribo*. Swammerdam dismissed the drawing as being 'devised upon a weak and erring memory, or feigned from mere imagination.' (b) Swammerdam's dissection of a male may-fly nymph from *Ephemeri Vita* (1675). © Bibliothèque centrale MNHN, Paris, reproduced with permission.

Ten years after Boerhaave acquired the papers, the *Bybel der Natuure* ('The Bible of Nature' – Boerhaave took the title from one of Swammerdam's letters to Thévenot) was published in Dutch, accompanied by a Latin translation, in two handsome folio volumes (1737 and 1738; see Fig. II). The first volume, complete with a biographical introduction by Boerhaave that still forms the basis of our knowledge of Swammerdam's life, marked the centenary of Swammerdam's birth. Nearly 60 years after the work was completed the second volume appeared as Boerhaave lay on his deathbed.

The scientific ambition represented by *The Book of Nature* is astonishing. Even today it shocks by its audacity. In its scope and depth, Swammerdam's work far exceeded any other book of the time. A comparison with the work of Hooke and Malpighi (Table I) is extremely telling: Swammerdam's vision (in every sense of the term) far exceeded that of his illustrious contemporaries. Although laying the basis for much of modern biology (in particular entomology), *The Book of Nature* is clearly very much of its time. It is full of charming pre-modern digressions, such as a tall tale of a maidservant trying to thread woodlice thinking they were pearls, a useful description of how to go fishing using cormorants and an ingenious technique for engraving pictures on snail shells.

A German translation appeared in 1752 (*Bibel der Natur*), followed by English translation in 1758, under the mistranslated title *The Book of Nature*, by which it is generally known today. A slightly reduced facsimile of the English edition produced in 1978 by Arno Press is still available (www.scry.com/ayer/BIOL0001/4411130.HTM).

Notes and references

a Letter from Boerhaave to Bassard, 9.9.1735. In Lindeboom, G.A., ed. (1965) *Boerhaave's Correspondance* (Vol. II), p. 341, E.J. Brill

b Editorial comment by Boerhaave in Swammerdam, J. (1758) *The Book of Nature* (Vol. I),

TABLE I COMPARISON OF HOOKE'S *MICROGRAPHIA* (1665), MALPIGHI'S *DE BOMBYCE* (1669) AND SWAMMERDAM'S *BOOK OF NATURE* (COMPILED 1676–1679)

	Pages	Words	Plates	Figures	Species
Micrographia	245	135,000	26	62	32
De Bombyce	100	57,000	11	48	8
The Book of Nature	389[a]	350,000	53	507	>60

Hooke's book, which contains no dissections, ranges over the whole natural world, from crystals to the moon, with only a proportion devoted to organic objects, many of which (seeds, leaves, cork) are presented for their striking visual impact. As a comparison, the great microscopist Antoni van Leeuwenhoek (1632–1723) published over 200 articles in the *Philosophical Transactions of the Royal Society* alone (Swammerdam published two). However, he never gathered his work in one place.

[a]*The Book of Nature* also contains 63 pages of detailed figure captions.

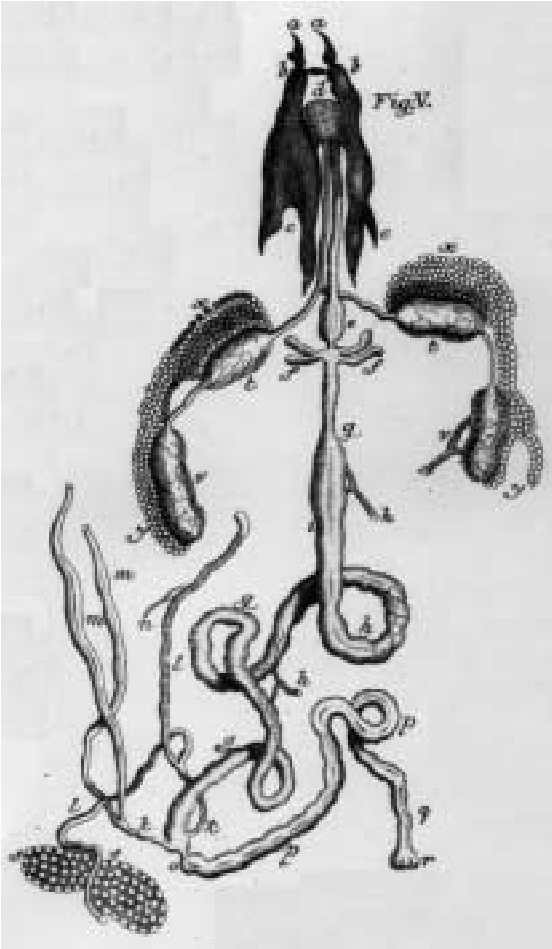


Figure 2 Dissection of the digestive system of the cheese skipper (*Piophila casei*) larva (3 mm long) from *The Book of Nature*. © Bibliothèque centrale MNHN, Paris. Reproduced with permission.

In both cases – butterflies and flies – Swammerdam was right. In a bold step that laid the basis of a materialist understanding of development, he showed that there was no spontaneous generation and that the same organism was present in egg, larva, pupa and adult. He did not put forward a theory of 'preformation'. Indeed, he was loath to speculate in any way, preferring to rely on the results of his (generally accurate) observations.

As to his remarks about the eggs of Adam and original sin, two points need to be made. First, this was based in part on his striking observation that eggs could be seen in the ovaries of unborn female mammals. Given that life apparently receded beyond the resolution of the microscope (for example, he found worms within the worms he observed inside the snail's uterus), or, as Swift was later to remark satirically

> So, naturalists observe, a flea
> hath smaller fleas that on him prey;
> And these have smaller fleas to bite 'em,
> And so proceed ad infinitum

it must have seemed possible that eggs might regress back to the origin of the world. This did not mean, however, that Swammerdam thought that these were fully formed individuals one within another.

Second, in the whole of *The Book of Nature*, Swammerdam makes only two passing remarks relating his view of preformation to his religious convictions. Far from forming the thrust of his work, this particular combination of science and theology is an insignificant (but interesting) detour that should not be taken as characteristic of his work. However, this raises an important point: religion did play a fundamental role in Swammerdam's life and science.

Empiricism and religion

As even a cursory reading of his work reveals, Swammerdam was driven by two powerful and contradictory motivations. On the one hand, he openly embraced what he called 'experimental philosophy', the Baconian principle that favoured empirical observation and experimentation above hearsay, 'authority' and pure reason. As a result, both the form and content of his research have a distinctly contemporary feel for today's scientists.

On the other hand, virtually every page of *The Book of Nature* contains pantheistic exhortations to praise the 'Supreme Architect' God (Christ is only mentioned three times), and uses the wonders revealed by the microscope and the dissecting instruments as proof of the glory of the Creator. Amazed by the beauty and order he discovered in the organisms he observed and dissected under the microscope, Swammerdam could only draw one conclusion: order could not be a product of chance, it must, therefore, be divine. This view was hardly unusual at the time – only Darwinism would free biology of such reasoning.

Swammerdam's opposition to spontaneous generation was not only motivated by his discoveries, but by his belief that it was 'the short path to atheism'[11]. As he explained in *The Book of Nature* 'For if the generation of things be so subject to chance, what prevents man from being thus as easily produced in the same manner.' However, in repeatedly asserting that insects were as complex as higher organisms and that 'The body of a beast deserves as great admiration as the human body, if we consider both in their kind and nature', he was asserting the unity of the natural world and unwittingly laying the basis for God's eventual departure from the scientific scene.

Although Swammerdam's repeated and lyrical expressions of wonder would have no place in a modern text[12], they are commonplace in contemporary scientific discourse, both in the informality of the laboratory and even in the more staid setting of a conference lecture. The religious framework is, of course, absent today, but the starting point – 'non-scientific' expressions of beauty and awe – is essentially the same.

Swammerdam's religious beliefs – rather vague and mystical, 'more catholic than reformed' as he described them[13] – not only informed his scientific investigations, they ultimately threatened their very existence. In the most notorious period of his life (1673–1676) he fell under the influence of the bizarre, itinerant French mystic, Antoinette Bourignon (1616–1680). Bourignon, who argued that Adam was hermaphrodite, heard voices and insisted that all her followers give up their worldly goods and preoccupations to follow her and worship Christ[14].

As a consequence of Bourignon's influence, Swammerdam abandoned science for a while (she described his work as 'amusements de Satan'[15]) and even destroyed his study of the silk-worm larva (although he had the good sense to send the drawings to Malpighi). Bourignon allowed him to publish his study of the may-fly, but it was undoubtedly her influence that led him to smother his findings with pages and pages of poems and religious reflections (see Box 2). After nine months living on her island off the coast of Schleswig, a disappointed Swammerdam returned to his father's home in Amsterdam in 1676.

Swammerdam's scientific judgement clearly suffered during his immersion in the Bourignon cult. Thus in *Ephemeri Vita* (1675), his monograph on the may-fly written at the height (or depth) of his religious infatuation, Swammerdam argued that 'the curing of human afflictions does not depend on the knowledge of anatomy or of any other science … but on the fear of the Lord.'[16] Three years later, in the conclusion to *The Book of Nature*, he had a far more lucid appreciation of the true value of his work:

> I believe physicians if they had clear and distinct ideas of the structure of our bodies, and of the motions of the blood, and other juices belonging to them, would be able to mend radically any unnatural disposition in these parts, as they could then prove the validity of such clear and distinct ideas, by reducing them to the test of experiments, which is allowed in every country to deserve credit, more than reason itself.

Swammerdam's religious beliefs also came into clear contradiction with his 'experimental philosophy'. Like many other early moderns, Swammerdam was highly critical of all those who blindly followed the views of the Ancients (essentially Aristotle). Indeed, he legitimately claimed that his work marked the first decisive advance on Aristotle for 2000 years! However, in one respect Swammerdam remained wedded to the argument of Authority: his view of the Bible, in particular the stories of the Old Testament.

Thus, in *The Book of Nature* he discusses at some length the story of Samson and the lion, the bees that nested in the dead lion's carcass and how they could have produced honey so rapidly. Even more bizarrely to modern eyes, having noted that metamorphosis in the butterfly leads to a change in the digestive apparatus, he wonders whether the King Nebuchadnezzar, who, in the Old Testament, turned into a grass-eating beast with a hairy hide and long talons and was cast into the wilderness, 'did not suffer a change in his internal parts, correspondent to that which appeared in his external form.'

In conclusion

Swammerdam did not have an easy life. Although he could have been part of the academic community, he never had a 'proper job'. He was perpetually plagued by financial problems and found himself in permanent conflict, first with his father, and then with his sister. In his personal life he swung between bouts of mystical intensity and a near-religious devotion to his scientific observations, with only a few close friends, such as Matthew Slade or Thévenot providing him with continual support and encouragement.

However, as his unending joy faced with the natural world makes clear, he was not a dour man. The care with which he reared a wide variety of insects in his room (and, indeed, on his body), carefully noting their habits and duration of development under different conditions shows that his delicate and precise methodology was not restricted to dissection. His view of insect behaviour and development, while lawful, was not mechanical or Cartesian. His delightfully anthropomorphic description of post-coital fatigue in the snail speaks volumes in terms of his attempt to understand animal behaviour and his conception of the factors that motivate animals.

Of all the natural historians of the 17th century, Swammerdam probably contributed most to the key debates of the time, by demonstrating that insects were just as complex as larger creatures and by showing that no example of 'spontaneous generation' could resist investigation. In this respect, he even surpassed Redi (1626–1697), a fierce opponent of spontaneous generation in general, but who accepted that gall-insects were produced by 'putrefaction'. Swammerdam's careful dissections proved him wrong and showed that they hatched from eggs laid by adults.

In the 18th century, Swammerdam's work became widely known following the publication of *The Book of Nature*. Less than six years after it appeared, Reaumur, one of the greatest scientists of the century, reproduced Swammerdam's dissection of bee ovaries in his book on bees, praising its quality. And Lyonet, whose work on insect anatomy built upon that of Swammerdam, said of his predecessor's work that it 'surpasses the imagination and savours of the prodigious'[17]. Indeed, whatever his mistakes, whatever the contradictions between his science and his mystical theology, Swammerdam made a massive contribution to the history of biology.

Notes and references

1 For an interesting attempt to demonstrate that there was a revolution in medicine in the 17th century, see Grmek, M.D. (1990) *La Première Révolution Biologique*, Payot

2 Wilson, C. (1995) *The Invisible World: Early Modern Philosophy and the Invention of the Microscope*, Princeton University Press

3 Fournier, M. (1996) *The Fabric of Life: Microscopy in the Seventeenth Century*, Johns Hopkins University Press

4 Ruestow, E.G. (1996) *The Microscope in the Dutch Republic: The Shaping of Discovery*, Cambridge University Press

5 te Rijdt, R.J.A. (1990) 'Een uitnemend geordonnerde en geteekende titel' door Jan Stolker. *Delineavit et Sculpsit* 6, 28–33

6 Schierbeek, A. (1967) *Jan Swammerdam (12 February 1637 – 17 February 1680), His Life and Works*, Swets & Zeitlinger

7 Cole, F.J. (1951) History of micro-dissection. *Proc. R. Soc. London Ser. B* 138, 159–187

8 Clutii, A. (1634) *Opuscula duo Singularia. I. de Nuce Medica. II. de Hemerobio size Ephemero Insecto, & Majali Verme*, Charpentier. A facsimile of this work has recently been produced, together with an English translation: Francissen, F.P.M. and Mol, A.W.M., eds (1984) *Augerius Clutius and his 'De Heremobio', an Early Work on Ephemeroptera*, Basilisken-Presse

9 Mason, S.F. (1962) *A History of the Sciences*, pp. 363–364, Collier

10 This is not strictly true. Clumps of cells, called pre-imaginal discs, that will form the future adult organs exist within the larva. In Pinto-Correia, C. (1995) *The Ovary of Eve: Egg and Sperm and Preformation*, University of Chicago Press, Clara Pinto-Correia argues that Swammerdam described these pre-imaginal discs, but for the moment the evidence is unconvincing.
11 Ironically, the opposite is true today: the only people who advocate a form of spontaneous generation are 'Creationists', whereas most scientists consider that religion and science are incompatible.
12 It could be argued that they represent a vestige of pre-modern approaches to nature. See Daston, L. and Park, K. (1998) *Wonders and the Order of Nature 1150–1750*, Zone Books. It has been suggested that Swammerdam's work 'banished magic' from natural history and that his expressions of wonder were how he 'compensate[d] for the loss of magic'. Thorndike, L. (1929) *A History of Magic and Experimental Science* Vol. VIII, pp. 56–57, Columbia University Press
13 Letter to Thévenot, January 1678. Lindeboom G.A., ed. (1975) *The Letters of Jan Swammerdam to Melchisedec Thévenot*, p. 84, Swets & Zeitlinger
14 As is often the case, the cult leader kept a tight grip on her own possessions. Bouquet, H. (1912) Le mysticisme d'un anatomist du XVIIe siècle: Jean Swammerdam et Antoinette Bourignon. *Æsculape*, pp. 171–176.
15 Lindeboom, G.A. (1974) Antoinette Bourignon's first letter to Jan Swammerdam. *Janus* 61, 183–199
16 Quoted in Schierbeek, A. (1967) *Jan Swammerdam (12 February 1637 – 17 February 1680), His Life and Works*, p. 46, Swets & Zeitlinger
17 Quoted in Cole, F.J. (1951) History of micro-dissection. *Proc. R. Soc. London Ser. B* 138, 159–187

Further reading

The main biographical sources for Swammerdam are Boerhaave's introduction to *The Book of Nature* and Schierbeek's biography[a]. In addition to the recent works cited in Notes and references[b,c,d], there is a thorough summary of Swammerdam's work in Winsor (1976)[e]. The impact of recent studies of microscopy on the history of science is discussed by La Berge (1999)[f]. Clara Pinto-Correia[g] provides a good summary of debates on preformationism. In the 19th century there was a Romantic revival of interest in Swammerdam, as reflected in Michélet's book *L'Insecte* (1856, 1876) and a 3-volume historical novel by H. Klencke, *Johannes Swammerdam* (1860). This interest in Swammerdam is revealed in a pastiche epic poem by A.S. Byatt in her 1990 novel *Possession*[h].

a Schierbeek, A. (1967) *Jan Swammerdam (12 February 1637–17 February 1680), His Life and Works*, Swets & Zeitlinger
b Wilson, C. (1995) *The Invisible World: Early Modern Philosophy and the Invention of the Microscope*, Princeton University Press
c Fournier, M. (1996) *The Fabric of Life: Microscopy in the Seventeenth Century*, Johns Hopkins University Press
d Ruestow, E.G. (1996) *The Microscope in the Dutch Republic: The Shaping of Discovery*, Cambridge University Press
e Winsor, M.P. (1976) Jan Swammerdam. In *DSB* (Vol. XIII) (Gillispie, C.C., ed.), pp. 168–175, Charles Scribner's Sons
f La Berge, A. (1999) The history of science and the history of microscopy. *Perspectives on Science* 7, 111–142
g Pinto-Correia, C. (1995) *The Ovary of Eve: Egg and Sperm and Preformation*, University of Chicago Press
h Byatt, A.S. (1990) *Possession*, Chatto & Windus.