

Images and Ideas: Leeuwenhoek's Perception of the Spermatozoa

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Henry Power, that optimistic devotee of the early microscope, warned in the 1660s that “our best Philosophers will but prove empty Conjecturalists, and their profoundest Speculations herein, but gloss'd outside Fallacies” if they did not exploit such new instruments.¹ He himself looked to the further confirmation and elucidation of the corpuscular natural philosophy,² but in the following decades the most consequential revelations of the microscope might reasonably have been expected to pertain more specifically to biological generation. No other question in seventeenth-century and eighteenth-century science was more laden with philosophical and religious overtones, for it asked if and how a despiritualized, mechanistic nature could engender the purposeful complexity of living organisms, including man.

As such exceptional observers as Marcello Malpighi, Jan Swammerdam, and Antoni van Leeuwenhoek probed various instances of generation with their microscopes, the community of the learned, the “Republic of Letters,” waited for some decisive new testimony. For Leeuwenhoek, whose microscopes were the finest before the nineteenth century and whose persistence pushed early microscopy to its furthest limits, the generation of living things became an enduring preoccupation, and his observations and conclusions unsettled a recently recast consensus. However, these observations also revealed how little as yet — though Leibniz, for one, was convinced otherwise³ — the microscope could offer philosophy and how much, rather, it ultimately supported a resurgent skepticism. Probing the limits of what could then be observed in the minute mechanisms of living things, Leeuwenhoek's instruments seemed in the end to reaffirm that the fundamental processes of generation would remain unknown.

1. Henry Power, *Experimental Philosophy, in Three Books* (London: printed by T. Roycroft for John Martin and James Allestry, 1664), p. [xviii] in “The Preface to the Ingenious Reader.”

2. *Ibid.*, pp. [vii-viii].

3. See Gottfried Wilhelm Leibniz, *Die philosophischen Schriften*, ed. C. I. Gerhardt (Hildesheim: Georg Olms, 1960-1961), IV, 474, 480.

Leeuwenhoek's acquaintance with the philosophical and religious concerns that intrigued the learned was limited, but it expanded considerably during the half-century of his microscopic research. A tradesman and minor municipal official in Delft, he lacked any university education and knew no language other than Dutch — no small obstacle to a familiarity with the doings of the Republic of Letters even if the inclination had been there. But he himself volunteered that as a youth, at least, he had had little interest in studies.⁴ In 1673, however, Leeuwenhoek's fellow townsman, the prominent young anatomist Regnier de Graaf, brought him to the attention of the Royal Society in London as a maker of exceptional microscopes.⁵

It was a turning point in Leeuwenhoek's life and the beginning of a long and loyal relationship with that eminent foreign association of virtuosi, to whom during the next fifty years he would address the great majority of the letters in which he revealed his observations and discoveries. His initial interest in the microscope probably stemmed from his enduring delight in his own manual skills and technical ingenuity, but in time his new acquaintances and their continuing encouragement of his observations cultivated a taste for speculation as well. He became conscious of thinking otherwise than did the "common man" and would assert in later years that he wrote for the "philosophical" alone.⁶ Through his correspondence and a growing number of learned and eminent visitors, he became increasingly familiar with the problems that interested Europe's intellectual elite, and though he was far from uncritical of what he heard, it did affect the focus of his researches and the quality of his thinking.

He was initially sensitive about the limitations of his background and during the first years of his growing celebrity asked even sympathetic supporters to "always remember who I am" when passing judgment on

4. Antoni van Leeuwenhoek to Henry Oldenburg, 7 September 1674, in Leeuwenhoek, *Alle de Brieven* (Amsterdam: Swets & Zeitlinger, 1939-), I, 166-167. Cited hereafter as Leeuwenhoek, *A.d.B.*

5. Regnier de Graaf to Henry Oldenburg, 18 April 1673, in Oldenburg, *Correspondence*, ed. and trans. A. Rupert Hall and Marie Boas Hall (Madison: University of Wisconsin Press, 1965-), IX, 602-603.

6. Leeuwenhoek to Antonie Heinsius, 17 December 1712, in Leeuwenhoek, *Send-Brieven* (Delft: Adriaan Beman, 1718), p. 22; Leeuwenhoek to the Royal Society, 10 July 1686, *A.d.B.*, VI, 128-129; Leeuwenhoek to Hendrik van Bleysswyk, 28 December 1695, in Leeuwenhoek, *Sesde Vervolg der Brieven* (Delft: Henrik van Krooneveld, 1697), p. 186; Leeuwenhoek to the Royal Society, 15 June 1717, *Send-Brieven*, p. 372; Leeuwenhoek to the Royal Society, 20 November 1717, *ibid.*, p. 453.

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his offerings.⁷ The elder Constantijn Huygens, prominent among those early supporters, felt compelled to point out to the Royal Society that their new correspondent was “unlearned both in sciences and languages,” but noted too that Leeuwenhoek was “always modestly submitting his experiences and conceits about them to the censure and correction of the learned.”⁸

Entering into these new relationships at the age of forty, however, Leeuwenhoek had a self-assured and assertive streak as well. In one of his earliest letters to Henry Oldenburg, secretary of the Royal Society, Leeuwenhoek explained that he had not previously committed his observations to paper in part because of a lack of schooling and literary ability, but in part also because of an impatience with contradiction and criticism.⁹ Though he solicited objections to his observations from his new correspondents and repeatedly assured them of his commitment to openly acknowledging and correcting his errors,¹⁰ Leeuwenhoek also wrote as early as 1674 of his resolve to stand by his speculations until he was better informed or in possession of new and better observations.¹¹ He responded to early skepticism in intellectual circles abroad with unruffled self-confidence.¹²

On one issue, whether the male semen or the female egg was the origin of mammalian generation, Leeuwenhoek indeed soon assumed a

7. Leeuwenhoek to Henry Oldenburg, 4 December 1674, in Leeuwenhoek, *A.d.B.*, I, 202-203; Leeuwenhoek to Constantijn Huygens, 26 December 1674, *ibid.*, pp. 206-207; Leeuwenhoek to Henry Oldenburg, 9 October 1676, *ibid.*, II, 142-143; Leeuwenhoek to Lambert van Velthuysen, 14 November 1679, *ibid.*, III, 136-139.

8. Constantijn Huygens to Robert Hooke, 8 August 1673, in Huygens, *Briefwisseling*, ed. J. A. Worp (The Hague: Martinus Nijhoff, 1911-1917), VI, 330-331.

9. Leeuwenhoek to Henry Oldenburg, 15 August 1673, in Leeuwenhoek, *A.d.B.*, I, 42-43.

10. Leeuwenhoek to Henry Oldenburg, 30 October 1676, *ibid.*, II, 164-165; Leeuwenhoek to Nehemiah Grew, 31 May 1678, *ibid.*, pp. 356-357; Leeuwenhoek to Robert Hooke, 3 March 1682, *ibid.*, III, 384-385; Leeuwenhoek to the Royal Society, 12 August 1692, in Leeuwenhoek, *Derde Vervolg der Brieven* (Delft: Henrik van Kroonevelt, 1693), p. 507; Leeuwenhoek to a “Hoog Geleerde Heer,” 16 June 1700, in Leeuwenhoek, *Sevende Vervolg der Brieven* (Delft: Henrik van Kroonevelt, 1702), p. 274; Leeuwenhoek to the Royal Society, 4 November 1704, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.69, fol. 320^r.

11. Leeuwenhoek to Henry Oldenburg, 4 December 1674, in Leeuwenhoek, *A.d.B.*, I, 202-203.

12. Leeuwenhoek to Henry Oldenburg, 22 January 1675, *ibid.*, pp. 210-211; Leeuwenhoek to Henry Oldenburg, 26 March 1675, *ibid.*, pp. 278-279; Leeuwenhoek to Henry Oldenburg, 20 December 1675, *ibid.*, pp. 330-331; Leeuwenhoek to Nehemiah Grew, 25 April 1679, *ibid.*, III, 22-23.

position of aggressive opposition to the general consensus of the medical community, an opposition that at times bordered on defiance of the whole academic tradition of learning. Convinced by his microscopic observations of the primary role of the semen, Leeuwenhoek was undaunted by the contrary authority of "your Harvey," he wrote Nehemiah Grew in 1678, "and our de Graaf" and expected the Royal Society to trust what he, Leeuwenhoek, had written.¹³ Add Harvey and de Graaf to seventy other authors cited as having similar views, he assured the Royal Society seven years later, or indeed to seventy times seventy authors, and he would still say they all had erred.¹⁴ For he knew "that I should not trouble myself over those who contradict me, for if someone gathered together all the old and new authors who have written about the flesh, muscular movement, blood, milk, fat, brains, skin, hair, bone, phlegms, etc., seldom would any be found who agree with what I write."¹⁵ He had heard a good deal by now of learned opinions, but he put greater faith in his microscopes and his own native intelligence.

Leeuwenhoek first became involved with the subject of animal generation with some hesitation, not because he was uncertain about his observations and opinions but because he questioned their propriety. Among the substances Henry Oldenburg had urged his new correspondent to study with his microscopes was semen; acquiescing to the request, Leeuwenhoek had discovered what he then took to be globules, but he was repelled by the inquiry and even more by the prospect of having to discuss it and quickly turned to other matters.¹⁶ Three or four years later, however, in 1677, a student from the medical school at Leiden, Johan Ham, brought him a specimen ostensibly of semen in which Ham himself had found small animals with tails, which Leeuwenhoek now observed as well.¹⁷ Leeuwenhoek resumed his own

13. Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, II, 328-339, esp. 332-339.

14. Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, V, 150-153.

15. *Ibid.*, pp. 172-173.

16. Leeuwenhoek to William Brouncker, November 1677, *ibid.*, II, 290-291.

17. *Ibid.*, pp. 280-283; Leeuwenhoek to Lambert van Velthuysen, 13 June 1679, *ibid.*, III, 74-75; Leeuwenhoek to Herman van Zoelen, 17 December 1698, in Leeuwenhoek, *Sevende Vervolg*, p. 65.

The donor of the specimen was a patient afflicted with gonorrhoea, and since the discharge symptomatic of the disease was often identified with semen, it is not unlikely that the specimen was in fact this gonococcal discharge. (Regarding the instruction at Leiden in particular, see Ham's own relative Theodorus Craanen, *Tractatus physico-medicus de homine* [Leiden: Petrus vander Aa, 1689], p. 750, and Gysbertus van Tol, *Disputatio medica inauguralis, de gonorrhoea virulenta* [Leiden: Vidua & Haeredes Johannis Elsevirii, 1674], Caput I, S. 5; see also

observations and in his own semen — acquired, he stressed, not by sinfully defiling himself but as a natural consequence of conjugal coitus — observed a multitude of “animalcules,” *dierpjes*, less than a millionth the size of a coarse grain of sand and with thin, undulating transparent tails.¹⁸

A month after Ham's visit, Leeuwenhoek described these observations in a brief letter to Lord Brouncker, president of the Royal Society. Still uneasy about the subject matter, Leeuwenhoek set this letter apart from his others by having it translated and sent in Latin, thought to protect modest sensibilities,¹⁹ and begged Brouncker to suppress it if

Regnier de Graaf, *Tractatus de virorum organis generationi inservientibus*, in *Opera omnia* [Leiden: Officina Hackiana, 1677], pp. 88-89.) I am grateful to Dr. F. Marc Laforce of the University of Colorado School of Medicine for reassurance that it is not unusual to find spermatozoa in such discharge.

It is possible that Ham himself had already made other observations of spermatozoa in healthy specimens of semen, for Fridericus Schrader of Helmstad, who had enrolled in the medical school at Leiden shortly after Ham's visit (his second, in fact) to Leeuwenhoek and graduated two years later, wrote in 1681 that his “very dear friend” Ham had first discovered spermatozoa in the Netherlands in the semen of a rooster. (*Album studiosorum Academiae Lugduno Batavae MDLXXV-MDCCCLXXV* [The Hague: Martinus Nijhoff, 1875], col. 616; “Catalogus promotorum,” in P. C. Molhuysen, ed., *Bronnen tot de Geschiedenis der Leidsche Universiteit* [The Hague: Martinus Nijhoff, 1913-1924], III, 331.) Ham had also told him, Schrader added, that he had found all the spermatozoa dead in the semen of those suffering from “virulent” gonorrhoea. (Fridericus Schrader, *Dissertatio epistolica de microscopiorum usu in naturali scientia & anatome* [Göttingen: Sumptibus Bartholdi Fuhrmanns, typis Johannis Christophori Hampii, 1681], pp. 34-35.) On 12 January 1679 in Bologna, moreover, Marcello Malpighi noted the report of a “German friend” (Schrader?) that “animals like extremely small toads, dead and deprived of motion,” could be observed in the semen of those with gonorrhoea. (Howard B. Adelman, *Marcello Malpighi and the Evolution of Embryology* [Ithaca, N.Y.: Cornell University Press, 1966], I, 420.) According to Leeuwenhoek, however, both he and Ham had observed living spermatozoa in the specimen that the latter had brought, and Ham had judged that they lived perhaps twenty-four hours; Ham also reported having observed them dead after the patient had taken turpentine (Leeuwenhoek to William Brouncker, November 1677, in Leeuwenhoek, *A.d.B.*, II, 282-283.) See also note 24.

18. Leeuwenhoek to William Brouncker, November 1677, in Leeuwenhoek, *A.d.B.*, II, 284-291.

19. Pieter Rabus, friend and admirer of Leeuwenhoek as well as publisher of the Dutch-language periodical *De Boekzaal van Europe*, restrained his discussion of some of Leeuwenhoek's later observations because he knew the *Boekzaal* was also seen by “delicate eyes” (*De Boekzaal van Europe*, VII [July-December 1695], 473) and suggested to Leeuwenhoek that he translate certain of his ideas on the impregnation of the female into Latin to make them known to the world. (Leeuwenhoek to Pieter Rabus, 30 November 1694, in Leeuwenhoek, *Vijfde Vervolg*

he thought it would give offense.²⁰ Such scruples were not peculiar to Leeuwenhoek or his social class, for even the elder Huygens, cosmopolitan sophisticate that he was, would not broach the subject with his middle-aged son, Christiaan.²¹ But Leeuwenhoek's fears about the possible offensiveness of his letter suggest how little he knew of the intense interest the subject of generation had aroused in medical circles during the immediately preceding decades.

Despite the delicacy of the matter, the elder Huygens wrote Leeuwenhoek that the observations in the letter to Brouncker were as important as anything that had yet been seen, while Christiaan would consider the spermatozoa the most important of the microscope's discoveries.²² Writers after Leeuwenhoek's death declared that the spermatozoa had given "a perfectly new Turn to the Theory of Generation" and set "the philosophic world spinning on another axis."²³

der Brieven [Delft: Henrik van Krooneveld, 1696], pp. 12-13.) In the bilingual catalogue of Leeuwenhoek's microscopes auctioned at Delft in 1747, preparations of spermatozoa and of the genitalia of fleas and lice were also specified in the Latin but not in the more modest Dutch text. (*Catalogus van het vermaarde Cabinet van Vergrootglazen, met zeer veel Moeite, en Kosten in veele Jaren geïnventert, gemaakt, en nagelaten door wylen den Heer Anthony van Leeuwenhoek* [Delft: Reinier Boitet, 1747], items 24, 28, 33, 35, pp. 10-11, 12-13, 14-15.)

20. Leeuwenhoek to William Brouncker, November 1677, in Leeuwenhoek, *A.d.B.*, II, 290-293. He was apparently reassured, for Leeuwenhoek's subsequent letters would deal unabashedly with his investigations of sex-related matters, and in 1679 he showed the spermatozoa of a dog to no one less than the visiting Duke of York. (Leeuwenhoek to Robert Hooke, 13 October 1679, *ibid.*, III, 106-109.) But he would continue on occasion to censor his speculations, for he feared not only their impropriety but "that the world, which is coarse and vicious enough, might use the knowledge of nature for its own ruin and increasingly debauch itself in depravity." (Leeuwenhoek to Pieter Rabus, 30 November 1694, in Leeuwenhoek, *Vijfde Vervolg*, p. 13.)

21. Text of letter from Constantijn Huygens to Leeuwenhoek, 8 December 1677, given in Leeuwenhoek to Herman van Zoelen, 17 December 1698, in Leeuwenhoek, *Sevende Vervolg*, pp. 68-69.

22. *Ibid.*; Christiaan Huygens, *Dioptrica*, in *Oeuvres complètes*, published by the Société Hollandaise des Sciences (The Hague: Martinus Nijhoff, 1888-1950), XIII, 524-527. For other examples of the spermatozoa being exalted above all of Leeuwenhoek's other observations, see Martin Folkes, "Some Account of Mr. Leeuwenhoek's Curious Microscopes, Lately Presented to the Royal Society," *Phil. Trans.*, 380 (November-December 1723), 449; Rudolphus Forsten, *Oratio de belgarum meritis in oeconomia corporis humani extricanda* (Harderwijk: Joannes Mooien, 1776), pp. 47-48.

23. Martin Folkes, "Some Account of Mr. Leeuwenhoek's Curious Microscopes," p. 449; Pieter Boddaert, *Natuurkundige Beschouwing der Dieren* (Utrecht: J. van Driel, [1778]), p. xxiii.

Leeuwenhoek himself did not at first attach exceptional significance to the spermatozoa, apparently regarding them as more of the microscopic life he was discovering in various waters and infusions. Christiaan Huygens, and perhaps even Ham, may well have suspected their relevance to reproduction before Leeuwenhoek.²⁴ Nonetheless, the letter to Brouncker did challenge the prevailing ideas about animal generation, supported indeed by the authority of William Harvey and Leeuwenhoek's late friend de Graaf, and led directly to persisting controversy.

Ironically, Leeuwenhoek's challenge rested initially on images that still remain unexplained.²⁵ Besides the spermatozoa, Leeuwenhoek had also observed the thicker part of the semen to be composed in large part of microscopic vessels, and in such numbers and variety, he wrote, that he was persuaded they were nerves, arteries, and veins. "Indeed, I have seen so many of these vessels that I believe I have observed more in a single drop of semen than an anatomist encounters during a whole day of dissection."²⁶ He wrote soon after, in early 1678, that he had seen these vessels again even more clearly than before, as distinctly indeed as the vessels in a dissected cat or rabbit were seen with the naked eye, and he had stood "with my thoughts as if dumbfounded" by so many wonders in so small a particle of matter.²⁷ Two months later, in May, he forwarded several drawings he had made of these tangled vessels, and though he noted that some of the vessels were so small they escaped his sight, the sketches betray no sense of hesitation or uncertainty;²⁸ as

24. Christiaan expressed his sense of the importance of the spermatozoa and their relevance to the generation of animals in announcing their discovery the following year in Paris. (Christiaan Huygens, "Extrait d'une Lettre de M. Huguens de l'Acad. R. des Sciences à l'Auteur du Journal, touchant une nouvelle maniere de Microscope qu'il a apporté de Hollande," *J. Scavans*, 15 August 1678, vol. 6, Amsterdam ed. [1679], 347.) Fridericus Schrader (see note 17) related that Ham, having first discovered the spermatozoa in the semen of a rooster, told him that he had also investigated the semen of sterile men, finding in it no spermatozoa at all, as well as the semen of those suffering from virulent gonorrhoea: (Fridericus Schrader, *De microscopiorum usu*, pp. 34-35.) If this is so, such a line of inquiry certainly suggests an interest in a possible connection between the spermatozoa and generation, although the date of these investigations is not disclosed.

25. Carlo Castellani, "Spermatozoan Biology from Leeuwenhoek to Spallanzani," *J. Hist. Biol.*, 6 (1973), 40; Leeuwenhoek, *A.d.B.*, II, 294n33, 295n31.

26. Leeuwenhoek to William Brouncker, November 1677, in Leeuwenhoek, *A.d.B.*, II, 292-295.

27. Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, pp. 336-339.

28. Leeuwenhoek to Nehemiah Grew, 31 May 1678, *ibid.*, pp. 364-367, and "Tables" 18 and 19.

baffling to modern observers as they were astonishing to him, the images seem to have appeared clear and crisp.

Whatever they may have been, these problematic vessels inspired or reflected a precise idea of the mechanism of generation. The observations convinced Leeuwenhoek that the human body contained no vessels that were not already in the semen, and he seems to have posited a very delicate, preembryonic vascular system that included the beginnings of the vital organs and already carried the animal spirits.²⁹ The assumption of a preformed structure within the semen had ancient roots³⁰ and gained increasing sway again in the seventeenth century with the resurgence of atomism and other variants of a mechanistic

29. Leeuwenhoek to William Brouncker, November 1677, *ibid.*, pp. 292-297; Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, pp. 336-337.

The English translation given in *A.d.B.*, II, for Leeuwenhoek's letter of 31 May 1678 to Nehemiah Grew introduces a very misleading idea. Leeuwenhoek's reference on p. 362 to spermatozoa among the ostensible vessels of the semen acquires in translation (p. 363) the sense that the spermatozoa came to be among the vessels "by their escaping from the vessels" when the latter were broken, suggesting that the spermatozoa had been contained within the vessels (see 362n29 and 363n9 in this volume of the *A.d.B.*). I find nothing in the original Dutch passage to justify the introduction of the cited phrase or the attendant implication. Leeuwenhoek initially wrote that he had observed the spermatozoa primarily in the thinner, fluid part of the semen around the thicker part, which, composed of vessels, was in fact too densely packed, he surmised, to allow the spermatozoa to move in it. (Leeuwenhoek to William Brouncker, November 1677, *ibid.*, pp. 284-287, 292-293.)

In his letter to Grew, Leeuwenhoek is attempting to explain how some spermatozoa were also found among the vessels. The answer he offers is that when the vessels were broken apart in the semen spilled as the male animal mounted the female, the spermatozoa were able to swim in among them. Since he had earlier observed (or so he reported) that these vessels, when exposed to the air for a few moments, turned into a watery substance and oily globules like those he had seen among the putative vessels of the spinal marrow as well, he conjectured that the vessels of the semen might in fact carry animal spirits (*ibid.*, pp. 294-297), presumably because the nerves and supposed vessels of the spinal cord were widely believed to carry these spirits. Leeuwenhoek indicated that the "body" – that is, the head – of the spermatozoa he had drawn for the Royal Society was perhaps slightly thicker than the prominent vessels of the semen he had drawn, the smaller of which, however, were so small as to escape his sight. (Leeuwenhoek to Nehemiah Grew, 31 May 1678, *ibid.*, pp. 364-367.) True to the near-equivalence of diameters thus suggested, he described the diameter of these prominent vessels as less than a hundredth the diameter of a large grain of sand (*ibid.*) and also judged that such a grain of sand would be larger in volume than a million spermatozoa. (Leeuwenhoek to William Brouncker, November 1677, *ibid.*, pp. 286-287.)

30. See Adelman, *Marcello Malpighi*, II, 730 ff.

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natural philosophy. Midcentury, the English physician Alexander Ross declared it to be "common opinion" that the "seed" contained all the parts of the future animal, while more than a decade before Leeuwenhoek's observations the French Jesuit Honoré Fabri had quite specifically, if very briefly, anticipated the idea of vascular rudiments in the semen.³¹ We can only assume that Leeuwenhoek brought a similar predisposition to his observations – which suggests, since his real introduction to learned speculations on generation appears to have followed the letter to Brouncker, how widespread the assumption of preformation in generation had become. Only subsequently, perhaps, did he fully realize how unorthodox it had become to locate that preformation still within the semen rather than in the egg. He responded with a persistent campaign to prove that he was right and recent opinion wrong, but in the process he abandoned the microscopic vessels for what was an even more unorthodox commitment to the spermatozoa.

It was Nehemiah Grew who, in responding to Leeuwenhoek's letter to Lord Brouncker, first addressed Leeuwenhoek's interpretation of the observations related therein. Raising doubts about the vessels, Grew outlined for Leeuwenhoek the prevailing understanding of mammalian generation, in fact a hard-won new synthesis that assumed the semen was "only the vehicle of a certain highly ethereal [*animalis*] and volatile spirit, which makes vital contact with the site of conception, that is, the female egg."³² Two opposing classical theories of conception had earlier vied for the loyalties of European scholars and physicians: the Aristotelian, which assumed that menstrual blood in the uterus formed the fetus under the influence of the semen, and the Hippocratic, which posited a female semen as well, that mixed with the male semen in the uterus.³³ In the Netherlands, Cartesians and traditionalists alike had generally adhered to the Galenic view, often presuming that the female semen derived from the female "testicles" (in fact the ovaries) and reached the uterus through the fallopian

31. Alexander Ross, *Arcana Microcosmi* (London: Tho. Newcomb, 1652), p. 230; Adelmann, *Marcello Malpighi*, II, 913.

32. [Nehemiah Grew], "Auctoris ad Observatorem Responsum," *Phil. Trans.*, 142 (December 1678 – February 1679), 1043. Regarding Grew's identity as the author of this response, see Leeuwenhoek to Nehemiah Grew, 18 March 1678, in Leeuwenhoek, *A.d.B.*, II, 326-333.

33. Jacques Roger, *Les Sciences de la vie dans la pensée française du XVIII^e siècle*, 2nd ed. (Paris: Armand Colin, 1971), pp. 53-63.

tubes.³⁴ The relative roles of the two semens, however, varied considerably from author to author, some still maintaining the Aristotelian contention that the impregnating principle of the male semen was incorporeal.³⁵

As Harvey himself acknowledged, the publication in 1651 of his *Exercitationes de generatione animalium* in London and Amsterdam made the question of generation far more difficult for everyone.³⁶ Dissecting a great number and variety of animals over the course of many years, he had found nothing in the uterus immediately after mating: no semen, male or female, and no sign of anything that had been conceived.³⁷ Only weeks later (in his particularly systematic study of the king's deer) did anything visible appear, a membranous sack extending throughout the uterus and filled with fluid, which Harvey chose to consider an egg.³⁸

The interim emptiness of the uterus before the appearance of the first signs of conception was subsequently confirmed in the Netherlands

34. René Descartes, "Primae cogitationes circa generationem animalium et nonnulla de saporibus," in *Oeuvres*, ed. Charles Adam and Paul Tannery (Paris: Léopold Cerf, 1897-1910), XI, 506-508; Henricus Regius, *Medicina, et praxis medica, medicationum exemplis demonstrata*, 3rd ed. (Utrecht: Theodorus ab Ackersdijck, 1668), p. 54; Gilbertus Jacchaeus, *Institutiones medicae*, 3rd ed. (Leiden: Joannes Maire, 1653), p. 84; Anton Deusing, *Synopsis medicinae universalis* (Groningen: Joannes Nicolai, 1649), p. 129; idem, *Idea fabricae corporis humani* (Groningen: Franciscus Bronchorstius, 1659), p. 140; Ysbrand van Diermerbroeck, *Anatomes corporis humani* in *Opera omnia*, ed. Timannus de Diermerbroeck (Utrecht: Meinardus à Dreunen & Guilielmus à Walcheren, 1685), p. 130. See also de Graaf, *Tractatus de virorum organis*, p. 91. Aristotle's contention that blood played a role in conception was still echoed at times in the Netherlands as well: Deusing, *Synopsis medicinae universalis*, p. 130; Gerard Blaes (Blasius), *Medicina generalis, novâ accuratâque methodo fundamenta exhibens* (Amsterdam: Petrus van den Berge, 1661), p. 102.

35. Anton Deusing, *Genesis microcosmi* [2nd ed.] (Amsterdam: Petrus van den Berge, 1665), pp. 53-54; *Idea fabricae corporis humani*, p. 140. On the Aristotelian background and seventeenth-century development of the idea of a spiritous or ethereal fecundating principle in the semen, see Carlo Castellani, "Origini ed evoluzione della teoria della «aura seminalis» da Fabrici d'Acquapendente a Marcello Malpighi," *Episteme*, 1 (1967), 173-196.

36. William Harvey, *Exercitationes de generatione animalium* (London: Typis Du-Gardianis, impensis Octaviani Pulleyn, 1651), p. 137.

37. *Ibid.*, pp. 226-229.

38. *Ibid.*, pp. 229-231.

(in rabbits) by de Graaf and Anthony Everaerts,³⁹ but it strained the ingenuity of the medical establishment.⁴⁰ In the late 1660s, prodded by comparative anatomy, a circle of anatomists associated with Leiden and including Jan Swammerdam, the Dane Nicolaus Steno, and de Graaf responded by redefining the female testicles as ovaries and the ovarian follicles as eggs.⁴¹ Swammerdam, who himself had perceived the ovaries as such in 1666, later ascribed the first assertion of this insight to Steno,⁴² but de Graaf's subsequent book, *De mulierum organis generationi inservientibus*, published in Leiden in 1672, contained the most developed exposition and exploration of the new hypothesis.

The proposition that man and other mammals produced eggs was a startling novelty and not without its problems, notably how the "eggs" got from the ovary to the fallopian tube and then passed through its initial narrows to the uterus,⁴³ a question as mysterious as any in all anatomy, acknowledged Swammerdam.⁴⁴ But de Graaf recognized that the true egg was in fact much smaller than the whole follicle and discovered in rabbits what he took to be the egg in the middle of the fallopian tube, whose extremity he found wrapped closely about the

39. Anthony Everaerts, *Novus et genuinus hominis brutique animalis exortus* (Middelburg: Franciscus Kroock, 1661), pp. 31-32, 35, 51; Regnier de Graaf, *De mulierum organis generationi inservientibus tractatus novus*, in *Opera omnia*, p. 397.

40. Harvey, *Exercitationes de generatione animalium*, p. 228.

41. Nicolaus Steno, "Historia dissecti piscis ex canum genere," in *Elementorum myologiae specimen, seu musculi descriptio geometrica* (Florence: ex typographia sub signo Stellae, 1667), pp. 117-118; Johannes van Horne, *Suarum circa partes generationis in utroque sexu observationum prodromus* (Leiden: Gaasbekios, 1668), p. [8]; Jan Swammerdam, *Miraculum naturae* (Leiden: Severinus Matthaei, 1672), pp. 19-20, 45; de Graaf, *De mulierum organis*, pp. 298, 302-303. The Leiden circle was apparently anticipated by several years, however, by Willem Langly, physician at Dordrecht; see Justus Schraderus, *Observationes et historiae omnes & singulae e Guiljelmi Harvei libello De generatione animalium excerptae* (Amsterdam: Abrahamus Wolfgang, 1674), "Praefatio," pp. [xiv]-[xv].

42. Jan Swammerdam, *Bybel der Natuure* (Leiden: Isaak Severinus, Boudewyn Vander Aa, Pieter Vander Aa, 1737-1738), I, 305; idem, *Miraculum naturae*, pp. 20, 54-55. Elsewhere Swammerdam wrote that the human "egg" was first known in 1667. (Jan Swammerdam, *Ephemeris vita* [Amsterdam: Abraham Wolfgang, 1675], pp. 9-10.)

43. Swammerdam, *Miraculum naturae*, pp. 19, 22-23; Ysbrand van Diemberoeck (*Anatome corporis humani, plurimis novis inventis instructa* [Utrecht: Meinardus à Dreunen, 1672], p. 218), offered other contrary arguments.

44. Swammerdam, *Bybel der Natuure*, II, 802, 804-805.

ovary.⁴⁵ Soon after de Graaf's publication even vigorous former adversaries in the Netherlands conceded that the presence of eggs in all kinds of animals was now "certain and unassailable."⁴⁶

The new pieces fit together in a new coherence but a coherence that seemed able to accommodate only a view of the male semen that stressed its ethereal nature. To the apparent absence of the semen in the uterus was now added the assumption that it impregnated the eggs while still in the ovary, so that the impregnating principle of the semen was variously described as spirit, vapor, odor, or "irradiation."⁴⁷ The tide against any material contribution by the semen was strong and rising when Leeuwenhoek proclaimed that the physical beginnings of the fetus were to be found in the semen alone.

The brevity of his letter to Lord Brouncker, his willingness to acquiesce in its suppression, and his intention, revealed later to Grew, to pursue the subject no further⁴⁸ all certainly reflect Leeuwenhoek's discomfort with the subject; but together with the absence of any reference to past or current opinion, they also suggest that Leeuwenhoek was not aware of how radical a departure from the new orthodoxy he was proposing. Grew was perhaps the first to inform him of Harvey's dissections and even of the importance and significance of de Graaf's own researches.⁴⁹ Leeuwenhoek was familiar with an engraving of the human ovaries and their "eggs" and had in the early 1670s seen such ovaries, presumably preserved, at two different places, perhaps de Graaf's and Swammerdam's.⁵⁰

45. De Graaf, *De mulierum organis*, pp. 348-349, 400-401.

46. Diemberbroeck, *Anatomes corporis humani* in *Opera omnia*, p. 131. Compare with the citation in note 43. Diemberbroeck died in 1674.

47. [Theodorus Craanen], "Exortus sive generatio hominis novus & genuinus," *Oeconomia animalis ad circulationem sanguinis breviter delineata* (Gouda: Guilhelmus vander Hoeve, 1685), p. 5; Diemberbroeck, *Anatomes corporis humani* in *Opera omnia*, pp. 132, 159, 163, 168, 179, 220; Steven Blanckaert, *Medicinae institutiones*, in *Opera medica, theoretica, practica et chirurgica* (Leiden: Cornelius Boutestein & Jordanus Lugtmans, 1701), I, 219, 273; Wolfertus Senguerdius, *Philosophia naturalis*, 2nd ed. (Leiden: Danieles à Gaesbeeck, 1685), p. 399; de Graaf, *Tractatus de virorum organis*, pp. 88, 92-93; idem, *De mulierum organis*, pp. 346-347; Swammerdam, *Bybel der Natuure*, II, 514-517; Antony Nuck, *Adenographia curiosa et uteri foeminei anatome nova* (Leiden: Jordanus Lugtmans, 1691), p. 69.

48. Leeuwenhoek to Nehemiah Grew, 18 March 1678, in Leeuwenhoek, *A.d.B.*, II, 334-335.

49. [Grew], "Auctoris ad Observatorem Responsum," p. 1043.

50. Leeuwenhoek to Nehemiah Grew, 18 March 1678, in Leeuwenhoek, *A.d.B.*, II, 342-343. Swammerdam publicized a human uterus he had prepared

Shortly after de Graaf's death in 1673, Leeuwenhoek had been told of intense arguments over the ovary, but the reference apparently pertained particularly to the clash between Swammerdam and de Graaf over priority and anatomical accuracy.⁵¹ It is not improbable that Leeuwenhoek remained ignorant of the history, implications, and details of the discussions of animal generation in academic circles. The pivotal works remained in Latin,⁵² and de Graaf, whose Latin treatises also betray a sensitivity to the possibility of his being reproached for impropriety,⁵³ may have been reluctant to expand on this complex and delicate issue with the unschooled tradesman whose microscopes he nonetheless admired.⁵⁴ Leeuwenhoek had attended de Graaf's physiological experiments on at least one occasion, but that particular experiment had not pertained to generation, and he had never observed a dissection of the animal uterus by de Graaf or anyone else.⁵⁵ The response to his conception of the role of the semen assured his further

as an example of his injected wax technique and also kept some preserved human "eggs" in his cabinet. (Swammerdam, *Miraculum naturae*, pp. 37-38, 46; *Ephemerita vita*, p. 10; *Bybel der Natuure*, I, 305.) Regarding the uterus and other prepared items, see also Swammerdam to Henry Oldenburg, 5 April 1672, in Oldenburg, *Correspondence*, VIII, 617-618; Oldenburg to Swammerdam, 19 December 1672 [O.S.], *ibid.*, IX, 367-369; and Swammerdam to Oldenburg, 24 January 1673, *ibid.*, pp. 411-413. De Graaf also made such anatomical preparations. (See Oldenburg to Swammerdam, 24 April 1672 [O.S.], *ibid.*, IX, 40, 42; Regnier de Graaf to Oldenburg, 12 July 1672, *ibid.*, pp. 137-138.)

51. Leeuwenhoek to the Royal Society, 19 March 1694, in Leeuwenhoek, *Vierde Vervolg der Brieven* (Delft: Henrik van Kroonevelt, 1694), pp. 670-671.

52. I have been able to locate no Dutch translation of de Graaf's *De mulierum organis generationi inservientibus tractatus novus* earlier than that in his posthumous *Alle de Wercken* (Amsterdam: Abraham Abrahamse), published in 1686. Nor have I been able to find a Dutch translation of Harvey's *Exercitationes de generatione animalium*.

53. De Graaf, *Tractatus de virorum organis*, "Praefatio," pp. [vi]-[viii]; *De mulierum organis*, pp. 158, 411.

54. When Leeuwenhoek speaks of de Graaf's having discussed such matters with mutual acquaintances (with medical training), he never suggests that de Graaf had spoken of them to Leeuwenhoek himself. See Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 170-171; Leeuwenhoek to the Royal Society, 19 March 1694, in Leeuwenhoek, *Vierde Vervolg*, pp. 670-671.

55. Leeuwenhoek to Robert Hooke, 14 January 1678, in Leeuwenhoek, *A.d.B.*, II, 310-313; Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, V, 159-161. See also Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, II, 332-336.

education, however, and it also prompted him, characteristically, to take up the knife himself.

Soon after he had heard from Grew, Leeuwenhoek undertook his own dissections of the genital organs of animals and launched a campaign against what he now understood to be the hypothesis so recently and carefully propounded by de Graaf. Obviously unaware of de Graaf's distinction between the follicle and the actual egg, Leeuwenhoek immediately proclaimed his astonishment that so much had been ascribed to vesicles that contained nothing but a watery fluid with globules that could be dislodged only with violence to surrounding tissues.⁵⁶ (Influenced in part by the early engraving he had seen, most likely Swammerdam's widely exposed but uncharacteristically fanciful depiction of eggs hanging on vessels within the ovary, Leeuwenhoek had expected to find them similarly loose within a hollow organ.⁵⁷) He would argue that they could not possibly pass through the narrow passages of the fallopian tubes and were to be found neither in these tubes nor in the uterus.⁵⁸ The mammalian ovaries were useless ornaments, he ultimately declared, and the sole function of the uterus and the female sex was to receive and nourish the masculine seed.⁵⁹

56. Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, II, 342-347.

57. *Ibid.*, pp. 342-343; Swammerdam, *Miraculum naturae*, facing p. 34; A. Schierbeek, *Jan Swammerdam: Zijn Leven en zijn Werken* (Lochem: "De Tijdstroom," [1946]), p. 114 and plate 5, facing p. 48. See also Gerard Blaes (Blasius), *Ontleding des menschelyken Lichaems* (Amsterdam: Abraham Wolfgangh, 1675), plate 17, fig. 1; Steven Blanckaert, *De nieuw hervormde Anatomie* [2nd ed.] (Amsterdam: Jan ten Hoorn, 1686), p. 463.

58. Leeuwenhoek to Christopher Wren, 22 January 1683, in Leeuwenhoek, *A.d.B.*, IV, 12-13; Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, V, 162-169, 188-191, 194-197.

Leeuwenhoek was later aware that both de Graaf and Malpighi had identified the ovarian follicle as the source of the ovum but not the ovum itself (Leeuwenhoek to the Royal Society, 19 March 1694, in Leeuwenhoek, *Vierde Vervolg*, pp. 659-660) but he did not alter his argument. (Leeuwenhoek to Gottfried Wilhelm Leibniz, 19 May 1716, in Leeuwenhoek, *Send-Brieven*, pp. 210-211; Leeuwenhoek to Gottfried Wilhelm Leibniz, 17 November 1716, *ibid.*, p. 301.) Regarding Malpighi, see Marcello Malpighi, "Praeclarissimo & eruditissimo Viro D. Jacobo Sponio . . .," *Phil. Trans.*, 161 (20 July 1684), 637-641; Adelman, *Marcello Malpighi*, II, 853, 859. With respect to de Graaf, see note 45.

59. Leeuwenhoek to the Royal Society, 19 March 1694, in Leeuwenhoek, *Vierde Vervolg*, pp. 663, 669-670; Leeuwenhoek to Gottfried Wilhelm Leibniz, 19 May 1716, in Leeuwenhoek, *Send-Brieven*, p. 211; Leeuwenhoek to Gottfried Wilhelm Leibniz, 17 November 1716, *ibid.*, p. 304. See also Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 204-205; Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, pp. 248-249; Leeuwenhoek to

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His dissections were the basis of a complete and unrelenting repudiation of mammalian eggs as sham, fantasy, and foolishness sustained by nothing better than obstinacy.⁶⁰ However, those dissections also produced a substantial change in the alternative Leeuwenhoek proposed.

At Grew's request Leeuwenhoek had proceeded to look for spermatozoa in other animals and had found them in great numbers in the semen of rabbits, dogs, and fish.⁶¹ He did not yet associate the spermatozoa with impregnation, however, or even intrinsically with the semen itself, for he believed during his early observations that they arose not with the microscopic vessels in the testicles but separately within the "male member."⁶² The only anticipation at this point of how his thinking would shift was occasioned when he again mistook the spermatozoa of fish for globules, each of which, he now reflected, might contain the beginnings of all the vessels of a fish.⁶³ Despite a supporting allusion to the many organs of movement within even smaller microscopic animals, he did not transfer his speculation on the beginnings of the future vessels of the fish to the spermatozoa when he finally recognized them for what they were.⁶⁴

For his early observations of semen Leeuwenhoek relied on residue acquired after the act of mating,⁶⁵ but in the spring of 1679 he wrote that for various unexplained reasons he had removed the testicles during the dissection of a male hare and had then cut the vas deferens.⁶⁶

the Royal Society, 10 June 1686, *ibid.*, VI, 120-123. Leeuwenhoek did believe, however, that the nourishment provided by the female in the uterus could alter the animal considerably. (Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, V, 250-251.)

60. Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 158-159, 164-165, 170-171; Leeuwenhoek to the Royal Society, 10 June 1686, *ibid.*, VI, 122-123; Leeuwenhoek to the Royal Society, 19 March 1694, in Leeuwenhoek, *Vierde Vervolg*, p. 666.

61. [Grew], "Auctoris ad Observatorem Responsum," p. 1043; Leeuwenhoek to Nehemiah Grew, 18 March 1678, in Leeuwenhoek, *A.d.B.*, II, 326-327, 340-349; Leeuwenhoek to Nehemiah Grew, 21 February 1679, *ibid.*, pp. 418-421.

62. Leeuwenhoek to Nehemiah Grew, 25 April 1679, in Leeuwenhoek, *A.d.B.*, III, 18-19.

63. Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, II, 340-341.

64. *Ibid.*; Leeuwenhoek to Nehemiah Grew, 21 February 1679, *ibid.*, pp. 418-421.

65. Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, pp. 328-329. For example, also see (apart from Leeuwenhoek's initial letter to Lord Brouncker) *ibid.*, pp. 338-341; Leeuwenhoek to Nehemiah Grew, 25 April 1679, *ibid.*, III, 10-11.

66. Leeuwenhoek to Nehemiah Grew, 25 April 1679, *ibid.*, III, 8-9.

Observing the matter the duct contained, he found it filled with an unbelievable multitude of spermatozoa (motionless, however, since the animal had been dead for several days), and when he cut the duct into pieces as he followed it back into the testicle, he continually found the same.⁶⁷ Cutting the testicle itself, he also found the spermatozoa in the filaments of which it was composed.⁶⁸ Similar dissections followed on dogs and fowl, which convinced him not only that the spermatozoa originated in the testicles but that the testicles in fact had no other purpose.⁶⁹ Those who have held that these animalcules play no role in procreation, he added, must now succumb⁷⁰ – as he had himself, he might have noted. The microscopic vessels, meanwhile, inexplicably faded away.⁷¹

Continued observations revealed staggering numbers of spermatozoa in the testicles and vasa deferentia of a widening variety of other animals,⁷² further confirming for Leeuwenhoek the essential identification of spermatozoa and semen. Though he had little hope of discovering the spermatozoa of the mite, he had succeeded with the flea; why, he asked, should that “perfection” in the semen of the flea not be found as well in the semen of even the very smallest animals?⁷³ Bolstered by these further observations, he was more explicit in 1683: he had long avoided speaking of man, but having found spermatozoa in the semen of mammals, birds, fish, and even insects, he wrote, he was now more certain than ever “that man comes not from an egg but from an animalcule in the masculine seed.”⁷⁴ He soon found a final answer as well to Harvey, whose failure to find semen in the uterus had been cited by Grew.⁷⁵ Leeuwenhoek had at first attempted to explain that absence as a consequence of the animal’s terrified reaction – akin to

67. *Ibid.*

68. *Ibid.*, pp. 8-11.

69. *Ibid.*, pp. 10-19; his conclusion is on pp. 18-19.

70. *Ibid.*, pp. 18-21.

71. Ultimately he completely repudiated his former accounts of the vessels in the semen (Leeuwenhoek to Christopher Wren, 22 January 1683, *ibid.*, IV, 8-11) concerning which he had once told the Royal Society he expected them to trust him. (Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, II, 336-339.)

72. Leeuwenhoek to Nehemiah Grew, 25 April 1679, *ibid.*, III, 10-19; Leeuwenhoek to Robert Hooke, 5 April 1680, *ibid.*, pp. 202-209; Leeuwenhoek to Robert Hooke, 12 November 1680, *ibid.*, pp. 314-325, 330-331.

73. Leeuwenhoek to Robert Hooke, 12 November 1680, *ibid.*, pp. 324-329.

74. Leeuwenhoek to Christopher Wren, 22 January 1683, *ibid.*, IV, 10-11.

75. [Grew], “Auctoris ad Observatorem Responsum,” p. 1043.

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miscarriage — to being tied down and cut open,⁷⁶ but in early 1685 he reported that with a good microscope he had found in the uterus and fallopian tubes of recently mated dogs and rabbits what had been invisible before, enormous numbers of living spermatozoa.⁷⁷

Leeuwenhoek pressed his campaign on several fronts throughout the 1680s, investigating the “supposed” eggs of the mammalian ovary again, attempting to determine how far and how fast the spermatozoa would travel in the uterus and how long they could survive, and repeatedly attempting to find them within the eggs of oviparous animals.⁷⁸ These eggs he considered genuine, but granted them, like the mammalian uterus, no other function than that of receiving and nourishing the spermatozoon.⁷⁹ Hoping that their smaller size would facilitate the discovery of that spermatozoon within, he turned in particular to the eggs of insects and other arthropods, but still found little more before the first signs of the embryo itself than globules and fluid.⁸⁰ In a systematic study of developing silkworm eggs, he thought he saw the spot where the spermatozoon had penetrated the shell, but no sign of an animal within appeared for two and a half months after the eggs were laid.⁸¹ He did succeed in discovering in the fluid of crab eggs he had crushed together (for when opened singly they dried too rapidly) animals so small that a hundred million together, he wrote, would not

76. Leeuwenhoek to Nehemiah Grew, 18 March 1678, in Leeuwenhoek, *A.d.B.*, II, 332-335.

77. Leeuwenhoek to the Royal Society, 5 January 1685, *ibid.*, V, 66-67; Leeuwenhoek to the Royal Society, 23 January 1685, *ibid.*, pp. 136-137; Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, pp. 154-155, 168-169.

78. Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, pp. 142-145, 184-189, 194-199; Leeuwenhoek to Christopher Wren, 16 July 1683, *ibid.*, IV, 64-69; Leeuwenhoek to the Royal Society, 10 June 1686, *ibid.*, VI, 112-113; Leeuwenhoek to the Royal Society, 11 July 1687, *ibid.*, pp. 316-319.

79. Leeuwenhoek to Christopher Wren, 16 July 1683, *ibid.*, IV, 58-59; Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, V, 178-179; Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, pp. 248-249; Leeuwenhoek to the Royal Society, 7 September 1688, *ibid.*, VIII, 14-15.

80. Leeuwenhoek to Christopher Wren, 16 July 1683, *ibid.*, IV, 66-69; Leeuwenhoek to the Royal Society, 10 June 1686, *ibid.*, VI, 104-105, 110-113, 116-117; Leeuwenhoek to the Royal Society, 11 July 1687, *ibid.*, pp. 314-315; Leeuwenhoek to the Royal Society, 2 March 1694, in Leeuwenhoek, *Vierde Vervolg*, p. 651.

81. Leeuwenhoek to the Royal Society, 11 July 1687, in Leeuwenhoek, *A.d.B.*, VI, 316-319.

equal the size of a coarse grain of sand.⁸² He was inclined to believe that they were, after all, the spermatozoa that had been within the eggs, but having failed thus far to see the true spermatozoa of the crab, he acknowledged he could not affirm this with certainty.⁸³

If observations were unable to confirm the continuity of spermatozoon and embryo, in the 1680s metaphysics helped to bridge the gap. In 1685 Leeuwenhoek reported finding within the uterus of a rabbit mated six days before a small, round vesicle the size of a millet grain that other authors, he said, would doubtless have called an egg but which he assumed to have derived from a spermatozoon.⁸⁴ Opening the vesicle — evidently a blastocyst, which de Graaf had observed in the rabbit only three days after mating and had indeed considered the egg — he briefly supposed he might have seen the figure of a rabbit a thousand times smaller than a grain of sand but abandoned this thought when he failed to find any such suggestion in other similar vesicles.⁸⁵ He concluded nonetheless that a body “animated [*besielt*] with a living soul from the male seed” had been enclosed within. Leeuwenhoek identified the “living soul” of an animal with an endowed capacity for movement,⁸⁶ and he repeatedly insisted, therefore, on the soul in each

82. Leeuwenhoek to the Royal Society, 10 June 1686, *ibid.*, pp. 112-113.

83. *Ibid.*, pp. 114-117. In 1695 he also wrote of having observed in the transparent fluid of early mussel eggs an abundance of small animalcules that he took for spermatozoa. (Leeuwenhoek to the Elector Palatine, 18 September 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 147.)

The first observations of spermatozoa penetrating and within an ovum did not come until the nineteenth century. See F. J. Cole, *Early Theories of Sexual Generation* (Oxford: Clarendon Press, 1930), pp. 193-195; Charles W. Bodemer, “The Microscope in Early Embryological Investigation,” *Gynecol. Invest.*, 4 (1973), 204-205. The mammalian ovum had itself been observed for the first time only shortly before. See George Sarton, “The Discovery of the Mammalian Egg and the Foundation of Modern Embryology,” *Isis*, 16 (1931), 315-[378].

84. Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 198-199. See also Leeuwenhoek to Christopher Wren, 22 January 1683, *ibid.*, IV, 10-13.

85. Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, V, 198-201; de Graaf, *De mulierum organis*, pp. 400-401; H. D. Jocelyn and B. P. Setchell, notes to *Regnier de Graaf on the Human Reproductive Organs (J. Reproduct. Fert. suppl. no. 17; Oxford, etc.: Blackwell Scientific Publications, 1972)*, 206n275.

86. Leeuwenhoek to the Royal Society, 13 July 1685, in Leeuwenhoek, *A.d.B.*, V, 246-247; Leeuwenhoek to the Royal Society, 6 August 1687, *ibid.*, VII, 34-35; Leeuwenhoek to the Royal Society, 12 January 1689, *ibid.*, VIII, 110-111; Leeuwenhoek to Antonio Magliabechi, 18 September 1691, *ibid.*, pp. 176, 184-185; Leeuwenhoek to the Royal Society, 7 March 1692, *ibid.*, pp.

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spermatozoon.⁸⁷ This being so, he wrote, it was a thousand times more probable that the living soul in the spermatozoon remained there as the body of the spermatozoon changed, so that the parts of the egg passed to the spermatozoon, rather than the living soul being transferred to the parts of the egg.⁸⁸ The identification of the impregnating principle of semen with microscopic animals nurtured an explicit metaphysical dimension in Leeuwenhoek's thought, doubtless encouraged by his growing familiarity with the philosophical inclinations of learned dialogue.

Other quasi-philosophical preconceptions helped shape his fundamental understanding of the spermatozoa and came now more explicitly to the fore. Innate motion signified animal life, animal life presumed a complex structure (for its motion alone, if nothing else), the lively microscopic bodies he discovered in various fluids were animals endowed with such complexity,⁸⁹ and the spermatozoa were such animals. The astonishing activity of the spermatozoa testified that they not only had souls, therefore, but that they had complex anatomic structures as well, with as many parts, wrote Leeuwenhoek in 1679, as could be imagined in the human body itself.⁹⁰ A succession of other ideas – preformed vascular systems in the semen, their possible encapsulation within seminal globules, the essential role of the spermatozoa in procreation – headed him toward a subsequent assumption that, like the spermatozoon's soul, its anatomic parts and structure persisted in the future animal. Perhaps implicit before but ambiguously expressed,⁹¹ Leeuwenhoek's presumption of the preformed man or

328-329. See also Leeuwenhoek to Antoni Cink, 24 October 1713, in Leeuwenhoek, *Send-Brieven*, p. 88.

87. Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 176-179; Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, pp. 248-249, 266-267.

88. Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, 176-179. See also Leeuwenhoek to the Royal Society, 11 July 1687, *ibid.*, VI, 330-331.

89. Leeuwenhoek to Nehemiah Grew, 18 March 1678, *ibid.*, II, 340-341; Leeuwenhoek to Nehemiah Grew, 27 September 1678, *ibid.*, pp. 390-391; Leeuwenhoek to Constantijn Huygens, 20 May 1679, *ibid.*, III, 56-67; Leeuwenhoek to Robert Hooke, 3 March 1682, *ibid.*, pp. 396-397; Leeuwenhoek to the Royal Society, 25 July 1684, *ibid.*, IV, 274-275; Leeuwenhoek to the Royal Society, 5 January 1685, *ibid.*, V, 20-21.

90. Leeuwenhoek to Nehemiah Grew, 25 April 1679, *ibid.*, III, 20-21.

91. Leeuwenhoek's comment footnoted immediately above might suggest that he already had in mind the idea of a preformed man in the spermatozoa, although elsewhere he similarly equated the complexity of microscopic animals in

animal within the spermatozoon was explicitly articulated in 1685, the same year as his commitment to the spermatozoon's living and persisting soul.⁹²

Not surprisingly, Leeuwenhoek detected some occasional and indirect evidence in varied observations to support his preconceptions,⁹³ but it was evidence that the preconceptions themselves had engendered. The observations that in Leeuwenhoek's mind argued most persuasively for the anatomic complexity and persistence of the spermatozoa rested also on analogy and misinterpretation of microscopic images. In the mid-1680s, when his reflections on the spermatozoa were acquiring a more metaphysical tone, he had undertaken extensive and related studies of the embryo plant in seeds. Like most of his contemporaries, Leeuwenhoek failed to recognize that plant seeds were themselves the product of sexual union,⁹⁴ and arguing that the propagation of varied living things was essentially the same, he insisted on an analogy between the embryo plant in the seed and the spermatozoon⁹⁵ – so much so

general with that of larger animals, including the human body. (Leeuwenhoek to Robert Hooke, 3 March 1682, *ibid.*, pp. 396-397; Leeuwenhoek to Constantijn Huygens, 20 May 1679, *ibid.*, pp. 58-59.) Thus no implications beyond a simple emphasis on the complexity of the spermatozoa can be ascribed with confidence to the cited passage. In 1683 Leeuwenhoek wrote that the inner body of the spermatozoa acquired the form of a man as "a whole other nature" (*een geheel ander wesen*) that is already provided with the heart and entrails, "indeed, all the perfection," of a man. (Leeuwenhoek to Christopher Wren, 22 January 1683, *ibid.*, IV, 16-17.) Whether the spermatozoa had all that perfection before assuming their new nature, however, is not clear.

92. Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, V, 236-237.

93. See Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, pp. 182-185.

94. Leeuwenhoek explicitly denied that plants mated. (Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, pp. 232-235, 246-247; Leeuwenhoek to the Royal Society, 10 June 1686, *ibid.*, VI, 120-121.) On the spreading recognition of plant sexuality in the 1690s and earlier, see Conway Zirkle, introduction to *The Anatomy of Plants* by Nehemiah Grew, Sources of Science, No. 11 (London: W. Rawlins, 1682; reprint ed., New York: Johnson Reprint Corporation, 1965), pp. xiv-xvi.

95. Leeuwenhoek to the Royal Society, 13 July 1685, in Leeuwenhoek, *A.d.B.*, V, 230-239; Leeuwenhoek to the Royal Society, 12 October 1685, *ibid.*, pp. 308-309; Leeuwenhoek to the Royal Society, 10 June 1686, *ibid.*, VI, 120-121; Leeuwenhoek to the Royal Society, 10 July 1696, in Leeuwenhoek, *Sesde Vervolg*, p. 279; Leeuwenhoek to the Royal Society, 23 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 102; Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fols.

that he declared in 1685 that his observations of seeds had rendered the propagation of animals from spermatozoa incontrovertible.⁹⁶

He was struck not merely by the presence of the embryo within the seed, which alone provided the seventeenth century with a suggestive analogy,⁹⁷ but by the microscopic structure he perceived within the embryo plant itself. Beginning in 1685 he repeatedly described not only the "leaves" and their beginnings in the embryo plant, but "vessels" – his perception of patterns of cells – in those parts from which the trunk and root of the tree would come.⁹⁸ These vessels numbered perhaps in the thousands, he suggested, and he spoke consequently of the unimaginable perfection in the seed and mused over the branching veins that still lay beyond the microscope.⁹⁹ In 1715 he wrote to Gottfried Leibniz of the 2,500 vessels in the seed of a pear and, in addition to an inconceivable number of other particles, reported what he took to be valves within the vessels as well.¹⁰⁰ As far as the microscope allowed, he wrote, he had observed thus the amazing structure in but a particle of the seed.¹⁰¹

239v-240f. Cf. Leeuwenhoek to Christopher Wren, 16 July 1683, in Leeuwenhoek, *A.d.B.*, IV, 66-67.

96. Leeuwenhoek to the Royal Society, 13 July 1685, in Leeuwenhoek, *A.d.B.*, V, 236-237, 262-264.

97. See Guiseppe degli Aromatari, "An Epistle Writ by Josephus de Aromatariis Concerning the Seeds of Plants, and Generation of Animals," *Phil. Trans.*, 211 (June 1694), 150-152; Antonius de Heyde, annotations in *Nieuw lichtende Fakkelt der Chirurgie of hedendaagze Heel-Konst* by Cornelis vande Voorde (Middelburg: Wilhelmus Goeree, 1680), 224n6; George Garden, "A Discourse Concerning the Modern Theory of Generation," *Phil. Trans.*, 192 (January-February 1691), 476.

98. Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 208-211; Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, pp. 218-223, 230-231, 258-259; Leeuwenhoek to the Royal Society, 13 June 1687, *ibid.*, VI, 252-309; Leeuwenhoek to Antonie Heinsius, 1 May 1695, in Leeuwenhoek, *Vijfde Vervolg*, pp. 44-45, 53. Leeuwenhoek usually made no distinction between the cotyledons and ordinary leaves (W. K. H. Karstens, annotation in Leeuwenhoek, *A.d.B.*, V, 218-219n4; 224-225nn16, 13), but see Leeuwenhoek to the Royal Society, 13 July 1685, in Leeuwenhoek, *A.d.B.*, V, 258-259.

99. Leeuwenhoek to the Royal Society, 13 July 1685, in Leeuwenhoek, *A.d.B.*, V, 220-223; Leeuwenhoek to the Royal Society, 13 June 1687, *ibid.*, VI, 308-309; Leeuwenhoek to Antonie Heinsius, 1 May 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 45.

100. Leeuwenhoek to Gottfried Wilhelm Leibniz, 18 November 1715, in Leeuwenhoek, *Send-Brieven*, p. 179.

101. *Ibid.*, p. 177.

He left no doubt in later years that these seeming vessels in the embryo plant were the vessels of the later tree, for if all the vessels of the tree were not in the seed, he insisted, how could the seed have produced the tree?¹⁰² Within each seed, consequently, was hidden all the perfection of the entire tree, including its fruit and seeds.¹⁰³ In 1687 or 1688 he undertook to discover the future ear of grain within the seed; failing in this, he remained certain that it was there and searched for and found it in the young dissected seedling.¹⁰⁴ He was already sure, moreover, that the future seeds were already formed within the ear and needed only to increase in size, so that within each ripened seed lay the beginnings not only of the ear but its seeds as well.¹⁰⁵ Which being so, he continued, we need doubt no more the perfection of the animalcule in the semen.

Leeuwenhoek seized upon his ostensible discovery of the internal structure of the future tree within the seed embryo as conclusive observational evidence that the spermatozoon similarly contained the structure of the future animal – conclusive evidence as well, consequently, of the central role of spermatozoa in animal generation. It was the discovery of the vessels within the embryo plant that in 1685 had rendered the propagation of animals from spermatozoa irrefutable, for although the figure of the animal within the spermatozoa still eluded him, he felt reassured all the same that it was there.¹⁰⁶ The

102. *Ibid.*, p. 176; Leeuwenhoek to Antonie Heinsius, 1 May 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 53; Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 234^r. Regarding his insistence that later organic forms had to be within the immediately antecedent forms, see also Leeuwenhoek to the Royal Society, 9 June 1699, in Leeuwenhoek, *Sevende Vervolg*, pp. 95-96; Leeuwenhoek to the Royal Society, 23 June 1699, *ibid.*, p. 103; Leeuwenhoek to Hans Sloane, 25 Dec. 1700, *ibid.*, pp. 305-306; Leeuwenhoek to "Hoog Doorlugtige Furst . . ." 20 April 1702, *ibid.*, p. 450; Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 238^v.

103. Leeuwenhoek to Antonie Heinsius, 1 May 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 57; Leeuwenhoek to the Royal Society, 10 July 1696, in Leeuwenhoek, *Sesde Vervolg*, pp. 278, 280; Leeuwenhoek to the Royal Society, 23 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 103; Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 238^v.

104. Leeuwenhoek to the Royal Society, 24 August 1688, in Leeuwenhoek, *A.d.B.*, VII, 372-387.

105. *Ibid.*, pp. 384-387.

106. Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, V, 236-237.

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recollection of such observations within the seed continued throughout the years to help sustain the conviction that "all the beginnings of the perfection with which a large creature (that has come from such a small animal) is provided," indeed the "entire man," lay already within the spermatozoon.¹⁰⁷ As the foundation for all his conclusions, however, and even, presumably, for his misinterpretation of images, lay the a priori intuition that the plant or animal had to have been enclosed in its beginnings. If all the wonders of the silk moth's anatomy had not been encompassed in the spermatozoon, he wrote in 1702 (as he had written so often of the seed), they could not have been produced from the spermatozoon.¹⁰⁸

This intuitive conviction in headier moments inspired vivid expectations. "I have in fact imagined," he also confessed in 1685,

that I could say as I beheld the animalcules in the semen of an animal that there lies the head and there as well the shoulders and there the hips; but since these notions have not the slightest shred of certainty, I will not yet put forward such a claim, but hope that we may have the good fortune to find an animal whose male seed will be so large that we will recognize within it the figure of the creature from which it came.¹⁰⁹

The seeming simplicity of his intuition, however, was entangled by difficulties that blur its ultimate and precise meaning for Leeuwenhoek. He had in fact written two years before (in an admittedly ambiguous passage) that the spermatozoon acquired a completely different nature – *wesen* (*wezen*) – when it found the proper place to nourish itself in the uterus. When he confirmed at the turn of the century that his contention was indeed that a lamb lay enclosed in the spermatozoon of a ram, he affirmed that this was true even though the parts within

107. Leeuwenhoek to Antonie Heinsius, 1 May 1695, in Leeuwenhoek, *Vijfde Vervolg*, pp. 53, 57; Leeuwenhoek to the Royal Society, 9 June 1699, in Leeuwenhoek, *Sevende Vervolg*, pp. 95-96; Leeuwenhoek to the Royal Society, 23 June 1699, *ibid.*, p. 105. See also Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fols 239^v-240^r.

108. Leeuwenhoek to "Hoog Doorlugtige Furst . . .," 20 April 1702, in Leeuwenhoek, *Sevende Vervolg*, p. 450.

109. Leeuwenhoek to the Royal Society, 13 July 1685, in Leeuwenhoek, *A.d.B.*, V, 236-237.

the spermatozoon did not resemble a lamb, whose form they assumed only when nourished in the womb.¹¹⁰

When in 1699 a celebrated hoax reported and illustrated the discovery of the lineaments of a man within a spermatozoon, Leeuwenhoek called it to the attention of the Royal Society in order to deny it, trusting, he said, that none of the society's members would accept the account as true.¹¹¹ If a spermatozoon were provided with all the perfected members capable of being recognized through the microscope, he reasoned, would they not remain in this same state of perfection as they grew? But in the developing chick, he pointed out (testifying as well to his broadened education), Malpighi had shown that this did not occur. Leeuwenhoek's own observations of early embryonic development had offered no less striking evidence against the animal's presence in the spermatozoon as a miniature replica; indeed, in extreme instances those observations would have been perceived by observers

110. Leeuwenhoek to Christopher Wren, 22 January 1683, *ibid.*, IV, 16-17; Leeuwenhoek to Hans Sloane, 25 December 1700, in Leeuwenhoek, *Sevende Vervolg*, p. 305.

111. Leeuwenhoek to the Royal Society, 9 June 1699, in Leeuwenhoek, *Sevende Vervolg*, pp. 92-95 (the relevant plate, which has been placed in the body of the wrong letter, is found facing p. 68). Concerning this hoax by Plantade (Dalenpatius), see Cole, *Early Theories of Sexual Generation*, pp. 68-72.

Curiously, Leeuwenhoek did not comment on Nicolaas Hartsoeker's earlier published depiction of what Hartsoeker supposed lay within a human spermatozoon – a tiny human body with an immense faceless head and the future umbilical cord running down the length of the spermatozoon's tail. (Nicolaas Hartsoeker, *Essay de dioptrique* [Paris: Jean Anisson, 1694], pp. 229-230. This work was also translated into Dutch as *Proeve der Deurzicht-kunde*, trans. A. Block [Amsterdam: Jan ten Hoorn, 1699].) Leeuwenhoek did respond to Hartsoeker's claim in this work to have been the first to have discovered spermatozoa (Leeuwenhoek to Herman van Zoelen, 17 December 1698, in Leeuwenhoek, *Sevende Vervolg*, p. 63 ff.), and there was no love lost between the two. Hartsoeker's illustration, however, was acknowledged to be pure speculation, making no claim, that is, to have succeeded with the microscope where Leeuwenhoek had so notably failed. But Leeuwenhoek's silence about this prominent illustration suggests that the basic assumption that the human body in *some distorted form* lay enclosed within the spermatozoa did not clash, after all, with Leeuwenhoek's own beliefs.

Leeuwenhoek also had earlier protested against a published report that attributed to him the idea that the semen was full of tiny infants, but his denial did not deal with what might lie within the spermatozoa. (Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 206-209. See also Steven Blanckaert, *Collectanea medico-physica*, 2-3 [1681-1682; published in Amsterdam: Johan ten Hoorn, 1683], 8; Cornelis Bontekoe, *Alle de philosophische, medicinale en chymische Werken* [Amsterdam: Jan ten Hoorn, 1689], I, 82.)

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with other predispositions as testifying conclusively that there was no persisting animal structure there at all.

Leeuwenhoek had already remarked as early as 1680 that the spermatozoon in the incubated chicken egg – in which he had in fact searched in vain for the spermatozoon in its original form – did not immediately assume and then grow in the form of the chick.¹¹² Searching in silkworm eggs in 1686-1687, he failed again to find the spermatozoa themselves, and when he finally detected the emerging caterpillar, he observed various globular parts along its length that he took for future limbs.¹¹³ The perfect louse with eyes, legs, and even claws that he discovered in its ten-day-old egg argued in 1696 that the supposed coagulation in the egg was after all only the expansion of the louse; but five years later he described how the transparent body of a newly hatched spider revealed its internal parts to be composed of globules like those he had seen lying in a fluid within the eggs, an observation hardly suggesting a continuous, preformed animal structure.¹¹⁴

Most unexpected, however (as similar observations must have been for Swammerdam as well),¹¹⁵ were observations Leeuwenhoek reported in 1688 of the embryonic development of the frog (observations which also led to his discovery of the capillary circulation of the blood, no small compensation for other, more problematic results). The eggs appeared to consist initially of an inconceivable number of rather complex globules in a watery fluid, and as he opened the changing and, in some cases, already moving eggs from day to day through the following week, he still saw only globules.¹¹⁶ Even the dissected body of a young free-swimming tadpole seemed to be composed of globules alone, with no intestines, nerves, or vessels. In later years, however, he insisted that although the form of the frog was not discovered in the tadpole, the frog lay enclosed there nonetheless,¹¹⁷ which must have meant to Leeuwenhoek the persisting if altered and invisible structure

112. Leeuwenhoek to Christopher Wren, 16 July 1683, in Leeuwenhoek, *A.d.B.*, IV, 64-67.

113. Leeuwenhoek to the Royal Society, 11 July 1687, *ibid.*, VI, 318-321.

114. Leeuwenhoek to Frederik Adriaan, Baron van Reede, 20 February 1696, in Leeuwenhoek, *Sesde Vervolg*, p. 203; Leeuwenhoek to the Royal Society, 21 June 1701, in Leeuwenhoek, *Sevende Vervolg*, pp. 352, 362-363.

115. Swammerdam, *Bybel der Natuure*, II, 813-819.

116. Leeuwenhoek to the Royal Society, 7 September 1688, in Leeuwenhoek, *A.d.B.*, VIII, 10-15.

117. Leeuwenhoek to the Royal Society, 9 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 92.

of the former spermatozoon as well. Observations could apparently support but not refute so fundamental a preconception.

The search for the ultimate confirmation of this preconception inspired recurrent assaults on the limits of his microscopes and ingenuity. The discovery of the future animal in one form or another within the spermatozoon would have been, after all, the crowning achievement of Leeuwenhoek's microscopy; and though he failed, it was not for lack of trying. He had observed the spermatozoa closely from the beginning. In his earliest exchange with Grew in 1678 he had already forwarded eight large drawings, magnified some two thousand times, of individual spermatozoa. Among them was a figure of a living human spermatozoon that was not surpassed in accuracy for another century and a half.¹¹⁸ He chafed nonetheless against the shortcomings of his techniques, still unable to provide a fully unobstructed view of a single, entire spermatozoon.¹¹⁹ He initially observed the semen, sometimes mixed with water, in capillary tubes,¹²⁰ but the method that ultimately provided his clearest and most penetrating observations was to dilute a small particle of semen with a drop of water and spread it as thinly as possible on a piece of glass, so that he saw the spermatozoa through the microscope, he wrote, as if lying in a field on a bright day.¹²¹ Still frustrated by how little he could see, he attempted to strip the spermatozoa of their outer skin with a small moistened brush as they lay dried upon the glass.¹²² The effort failed, and repeated attempts to

118. Leeuwenhoek to Nehemiah Grew, 18 March 1678, in Leeuwenhoek, *A.d.B.*, II, 346-349 and "Table" XVI; Arthur Hughes, "Studies in the History of Microscopy. 1. The Influence of Achromatism," *J. Roy. Microsc. Soc.*, ser. 3, 75 (1955), 15.

119. Leeuwenhoek to Nehemiah Grew, 18 March 1678, in Leeuwenhoek, *A.d.B.*, II, 348-349.

120. Leeuwenhoek to Nehemiah Grew, 31 May 1678, *ibid.*, pp. 362-363; Leeuwenhoek to the Royal Society, 15 April 1701, in Leeuwenhoek, *Sevende Vervolg*, pp. 321, 323.

121. Leeuwenhoek to the Royal Society, 9 June 1699, in Leeuwenhoek, *Sevende Vervolg*, pp. 99-100. He sometimes observed them by candlelight, with a small concave metal mirror to enhance the illumination. Though he would on occasion use a "very good and very magnifying" microscope in his observations of spermatozoa (Leeuwenhoek to the Royal Society, 6 August 1687, in Leeuwenhoek, *A.d.B.*, VII, 10-13), he could show them to visitors through an "ordinary" (*gemeen*) instrument. (Leeuwenhoek to Robert Hooke, 13 October 1679, *ibid.*, III, 108-109.)

122. Leeuwenhoek to the Royal Society, 15 April 1701, in Leeuwenhoek, *Sevende Vervolg*, p. 325.

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probe their inner structure yielded little more than suggestions of globular shapes.¹²³

Leeuwenhoek at times suspected that he might fleetingly have glimpsed something more,¹²⁴ but by the end of the century he accepted the barriers he confronted as final. A "great secret" was hid within both the seeds of plants and the semen of animals, and by the mid-1690s his efforts to probe ever deeper with his microscopes had only convinced him that this hidden secret could not be reached.¹²⁵ It was inconceivable, he wrote in 1699, "that human ingenuity will penetrate so deeply into that great secret that, by chance or by the dissection of the animalcule in the semen, we will come to see the entire man." Yet he had no doubt that the entire man – in whatever form – was there.¹²⁶ He reemphasized the following year that he considered it impossible (*ondoentlyk*) for man to penetrate the secret of the spermatozoon and added in 1703 that we had penetrated as deeply as we could into both semen and the seeds of plants; there was nothing more in that great secret we could discover.¹²⁷

Even farther beyond his microscope lay the origins of the spermatozoon (and the seed embryo) itself and, since the form of the animal was in some way already within the spermatozoon, the mechanisms of true generation – the process that first produced that form. At this inaccessible remove lay the decisive evidence relevant to the developing

123. Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 190-193 and "Table" XX, figs. 33 and 34. (See also the drawings of dead spermatozoa included with his letter of 18 March 1678 to Nehemiah Grew, *ibid.*, II, "Table" XVI.) Leeuwenhoek to the Elector Palatine, 18 September 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 146; Leeuwenhoek to the Royal Society, 9 June 1699, in Leeuwenhoek, *Sevende Vervolg*, pp. 98-99; Leeuwenhoek to Hans Sloane, 25 December 1700, *ibid.*, pp. 301-302 and figs. 2-6 in plate facing p. 300; Leeuwenhoek to the Royal Society, 15 April 1701, *ibid.*, p. 322.

124. Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 190-191; Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, pp. 236-237.

125. Leeuwenhoek to Antonie Heinsius, 1 May 1695, in Leeuwenhoek, *Vijfde Vervolg*, pp. 53-54. Concerning the great secret, see also notes 126 and 127 below, as well as Leeuwenhoek to the Royal Society, 23 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 105.

126. Leeuwenhoek to the Royal Society, 9 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 96.

127. Leeuwenhoek to Hans Sloane, 25 December 1700, *ibid.*, p. 306; Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 240^v.

disposition in learned circles to deny nature itself the power of generation, which was reserved to God alone and the cataclysmic act with which the world began. Anticipated in 1669 by Swammerdam, Nicolas Malebranche had in 1674 more fully and precisely advanced a theory of encapsulated preexistence that left a mechanistic nature with no other contribution to generation than a capacity for growth.¹²⁸ Successively diminishing generations of preformed individuals, all created together in the first creation of the world, were conceived to be enclosed one within the other in a virtually infinite encapsulated series. Reserving all creativity to the Mosaic God and purging mechanism of the specter of materialism, it was a religiously and philosophically compelling hypothesis that became the reigning orthodoxy by the early eighteenth century.¹²⁹ Swammerdam, Malebranche, and a multitude of followers located this primeval series within the egg, but Leeuwenhoek's letters provided the point of departure for a rival school of thought that posited the series within the spermatozoon.¹³⁰ From his insistence on the man within the spermatozoon (and the tree within the seed – an echo, knowingly or not, of Malebranche),¹³¹

128. Jan Swammerdam, *Historia insectorum generalis* (Utrecht: Meinardus van Dreunen, 1669), p. 51 in the first series in the pagination. (See also Swammerdam's *Miraculum naturae*, pp. 21-22; *Bybel der Natuure*, I, 34.) Nicolas Malebranche, *La Recherche de la vérité*, in *Oeuvres complètes*, dir. André Robinet (Paris: J. Vrin, 1958-1970), I, 81-83. (See also Malebranche, *Entretiens sur la métaphysique et sur la religion*, *ibid.*, XII, 228-229.)

129. Roger, *Les Sciences de la vie*, pp. 334-353, 364-384, 724, 731-732, 742.

130. See Cole, *Early Theories of Sexual Generation*, chaps. 4 and 5.

131. Malebranche, *La Recherche de la vérité*, p. 82. This book was translated into Dutch in 1680-1681 (Geneviève Rodis-Lewis, introduction to *La Recherche de la vérité*, p. xix), though there is no evidence that Leeuwenhoek actually read parts of it; nor is it likely that such an abstract theological and philosophical work would have interested him. Nonetheless, it is very probable that Leeuwenhoek was informed of some of Malebranche's arguments and illustrations. He had often heard, wrote Leeuwenhoek in 1685, that the flower itself could be seen within the tulip bulb – which he denied (Leeuwenhoek to the Royal Society, 12 October 1685, in Leeuwenhoek, *A.d.B.*, V, 302-303) – an observation that had played a prominent role in Malebranche's initial presentation of the idea of a series of encapsulated organisms, an *emboîtement*. (Malebranche, *La Recherche de la vérité*, p. 82.) Leeuwenhoek was familiar with Swammerdam's *Historia insectorum*, which had been written in Dutch (see Leeuwenhoek to Henry Oldenburg, 5 October 1677, in Leeuwenhoek, *A.d.B.*, II, 250-253; Leeuwenhoek to the Royal Society, 24 August 1688, *ibid.*, VII, 344-345, 350-351; Leeuwenhoek to the Royal Society, 7 September 1688, *ibid.*, VIII, 14-17), but Swammerdam's remarks about preexistent animals were brief and vague.

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Leeuwenhoek's own adherence to this logical elaboration of the simpler intuition might easily have been assumed, but he balked at taking this extreme position.

Leeuwenhoek avoided addressing the prospect of preexistence directly, but passages in his letters are unquestionably suggestive. In the spring of 1679, it is true, he rejected a claim that unborn mice already contained another future litter (completely at variance, though he did not mention this, with his convictions on the role of the semen). When his correspondent, Lambert van Velthuysen, a multifaceted Cartesian, theologian, and former magistrate at Utrecht, described in response "the contention of some learned people about the generation of plants and animals, that it did not take place anew," Leeuwenhoek briefly but diplomatically replied that van Velthuysen had elaborated on the idea so subtly and extensively "that I do not think I am fit or able to say anything about it."¹³² Particularly when rejecting spontaneous generation, however, Leeuwenhoek repeatedly stressed in later decades that living things derived (*afhangen, afkomstig zijn*) directly from the first creation,¹³³ and though it often seems clear he meant lineal descent and not the persistence of the individual, in 1687 and 1688 he remarked that no new creatures were made by God or were made "anew."¹³⁴ While urging the unimaginable perfection within the seed in 1687 as well, he added that he would have expanded further on his speculations on the derivation of all plants from those created in the beginning, but feared that to do so would give offense.¹³⁵ The following

132. Leeuwenhoek to Lambert van Velthuysen, 13 June 1679, in Leeuwenhoek, *A.d.B.*, III, 76-77; Leeuwenhoek to Lambert van Velthuysen, 11 July 1679, *ibid.*, pp. 86-87.

133. Leeuwenhoek to the Royal Society, 6 August 1687, *ibid.*, VII, 34-35; Leeuwenhoek to the Royal Society, 24 June 1692, in Leeuwenhoek, *Derde Vervolg*, p. 474; Leeuwenhoek to Frederik Adriaan, Baron van Reede, 20 August 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 135; Leeuwenhoek to the Royal Society, 23 June 1699, in Leeuwenhoek, *Sevende Vervolg*, pp. 103, 105; Leeuwenhoek to the directors of the East India Company in Delft, 5 August 1699, *ibid.*, p. 111; Leeuwenhoek to Antonio Magliabechi, 16 October 1699, *ibid.*, pp. 149-150; Leeuwenhoek to Nicolaas Boogaart, 14 January 1700, *ibid.*, p. 180; Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 238^v; Leeuwenhoek to the Royal Society, 22 September 1711, *ibid.*, EL.L4.40, fol. 152^f.

134. Leeuwenhoek to the Royal Society, 6 August 1687, in Leeuwenhoek, *A.d.B.*, VII, 34-35; Leeuwenhoek to the Royal Society, 24 August 1688, *ibid.*, p. 378.

135. Leeuwenhoek to the Royal Society, 13 June 1687, *ibid.*, VI, 308-309.

year he stated with certainty that within the ripened grain seed lay the beginnings of the future seeds, and he had written in 1685 that the beginnings of the spermatozoa were already in the preceding spermatozoon.¹³⁶ Such passages would be echoed later,¹³⁷ but the mid-1680s witnessed a particular efflorescence of such tantalizing phrasing, his imagination or his mode of expression perhaps loosened from their usual caution by his recent exposure to the more extravagant speculations current among the learned.

Despite such passages, however, the means by which the spermatozoa and embryo plants were themselves produced had baffled Leeuwenhoek from the beginning. He had clearly assumed in 1679 that spermatozoa, like other microscopic "animalcules" he had discovered, came themselves from a "seed" or semen — *saet* (*zaad*) — but whence came this *zaad* he could not imagine.¹³⁸ He resolved to investigate the question to the best of his ability,¹³⁹ but his approach remained very cautious. Confronting the problem again the following year, he puzzled over the long delay before the spermatozoa first appeared in a man and wondered whether one should suppose that the *zaad* lay there in the testicles of a boy for fourteen years or more before it came to life, reached full growth, and became fit for generation.¹⁴⁰ Backing away, Leeuwenhoek concluded that he would leave the problem to others.

The opinion that had earlier prevailed in the Netherlands, at least, that the semen was produced in the testicles from arterial blood (with some spirit or lymph mixed in) persisted after the discovery of the spermatozoa.¹⁴¹ Frederik Ruysch, a major architect of a new systematic

136. Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, V, 264-267; Leeuwenhoek to the Royal Society, 24 August 1688, *ibid.*, VII, 384-387.

137. Concerning the seeds being already enclosed within the preceding seed, see also Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 238v.

138. Leeuwenhoek to Lambert van Velthuysen, 13 June 1679, in Leeuwenhoek, *A.d.B.*, III, 78-79.

139. *Ibid.*, pp. 80-81.

140. Leeuwenhoek to Robert Hooke, 5 April 1680, *ibid.*, pp. 204-205.

141. See the following: Regius, *Medicina et praxis medica*, p. 54; Blaes, *Medicina generalis*, p. 67; Diemerbroeck, *Anatome corporis humani*, p. 193; *idem*, *Anatomes corporis humani in Opera omnia*, pp. 106, 110-111, 159-160; de Graaf, *Tractatus de virorum organis*, pp. 56-60, 92 (cf. 54-55); Senguerdius, *Philosophia naturalis*, p. 399; Nicolaas Hartsoecker, *Suite des conjectures physiques* (Amsterdam: Henri Desbordes, 1708), pp. 82, 107. But see also Everaerts, *Novus et genuinus hominis brutique animalis exortus*, pp. 2-6.

physiology resting on putative vascular microstructures,¹⁴² maintained that the semen was first made in vessels of the testicles that derived directly from the arteries, and Herman Boerhaave in Leiden, presiding over the academic medical community of Europe in the early eighteenth century, echoed him.¹⁴³ Attempts to explain the origin of the spermatozoa varied widely, from spontaneous generation – be it from putrefaction or a “tender digestion” (*lieflyke digestie*) of particles of chyle – to the initial suggestion of Leeuwenhoek's envious critic, Nicolaas Hartsoeker, that they came from the air we breathed and the food we ate and were separated out of the blood in the testicles, an idea he himself later found preposterous.¹⁴⁴

Boerhaave, who, though vacillating, was inclined to agree that the spermatozoa were the cause of fertilization,¹⁴⁵ pointedly urged Leeuwenhoek in his later years to investigate with his microscopes where in the male genitalia the spermatozoa first appeared and whether something similar to them might not be found in the blood of sexually aroused male animals just before it entered the testicles.¹⁴⁶ Leeuwenhoek obliged, but, as he anticipated, could find no animalcules in the arterial or venous blood of the testicles of an appropriately excited rabbit; nor did he find them in any of the other fluids of the body,

142. See Edward G. Ruessow, “The Rise of the Doctrine of Vascular Secretion in the Netherlands,” *J. Hist. Med. Allied Sci.*, 35 (1980), 272ff.

143. Frederik Ruysch, “Responsio,” in Abraham Vater, *Epistola gratulatoria* (Amsterdam: Janssonio-Waesbergios, 1727), p. 12; Herman Boerhaave, *Institutiones medicae*, 5th ed. (Leiden: Theodorus Haak, Samuel Luchtmans, & Joh. & Herm. Verbeek; Rotterdam: Joan. Dan. Beman, 1734), pp. 326-327; Herman Boerhaave and Frederik Ruysch, *Opusculum anatomicum de fabrica glandularum in corpore humano* (Leiden: Cornelius Haak, 1751), p. 43.

144. Leeuwenhoek to Nehemiah Grew, 25 April 1679, in Leeuwenhoek, *A.d.B.*, III, 18-19; Heidentryk Overkamp, *Nieuwe Beginselen tot de Genees- en Heel-Konst*, 2nd ed. (Amsterdam: Timotheus ten Hoorn, 1686), p. 423; Hartsoeker, *Suite des conjectures physiques*, p. 107; idem, *Recueil de plusieurs pieces de physique* (Utrecht: Veuve de G. Broedelet & Fils, 1722), p. 193.

145. Boerhaave, *Institutiones medicae*, pp. 342-343; idem, *Praelectiones academicae in proprias Institutiones rei medicae edidit*, ed. Albrecht von Haller, 2nd ed. (Göttingen: Abram Vandenhoeck, 1740-1744), V, pt. 2, 193; Herman Boerhaave and Albrecht von Haller, *Methodus studii medici emaculata* (Amsterdam: Jacobus a Wetstein, 1751), I, 251.

146. Herman Boerhaave to Leeuwenhoek, 10 October 1716, letter published in Luigi Belloni, “Leeuwenhoek, Boerhaave a Bleyswyk sugli spermatozoi,” *Physis*, 5 (1963), 328; Boerhaave, *Praelectiones academicae*, V, pt. 1, 350-352, 379.

Boerhaave later commented.¹⁴⁷ The microorganisms Leeuwenhoek had found about the teeth had come from the air, Boerhaave observed, but the spermatozoa arose where no external air could reach: hence, the preeminent figure in early eighteenth-century medicine confessed complete ignorance about how the spermatozoa arose.¹⁴⁸ The dilemma was similar to that which revolved around the origin of parasitic worms (among which, indeed, the spermatozoa were often included),¹⁴⁹ a persistently intractable problem that long provided a principal argument for spontaneous generation.¹⁵⁰

Despite his own hesitancy in speculating about the origin of the spermatozoa, Leeuwenhoek could hardly have banished such an obvious and tantalizing question from his thoughts. The initial discovery of spermatozoa in the testicles and vasa deferentia of various animals had been enough to convince him that the spermatozoa did not arise, at least, from spontaneous generation (that is, from putrefaction), but he denied that they had been present in man during the years preceding adolescence, for if they had been, he reasoned, the desire for copulation would have been felt then as well.¹⁵¹ In 1685 he wrote that when man reached a proper age, the spermatozoa then "were made" and "received life" from a substance that had already resided in the spermatozoon from which man himself had come, but this, he also noted, made matters harder still to understand.¹⁵²

It was a challenge essentially to his speculative ingenuity, and although microscopic observations did on occasion encourage certain lines of speculation, the images were too uninformative and their interpretation too uncertain to exercise any decisive sway. What he saw, however, he found consistent with the assumption that the spermatozoa

147. Leeuwenhoek to Herman Boerhaave, 5 November 1716, in Leeuwenhoek, *Send-Brieven*, p. 290; Leeuwenhoek to Herman Boerhaave, 21 November 1716, *ibid.*, pp. 308-313; letter from Abraham van Bleyswyk to Herman Boerhaave, published undated in Belloni, "Leeuwenhoek, Boerhaave e Bleyswyk," p. 330; Boerhaave, *Praelectiones academicae*, V, pt. 1, 352-353.

148. Boerhaave, *Praelectiones academicae*, V, pt. 1, 354.

149. Castellani, "Spermatozoan Biology," p. 48; John Farley, *The Spontaneous Generation Controversy from Descartes to Oparin* (Baltimore: Johns Hopkins University Press, 1977), p. 20.

150. See Farley, *The Spontaneous Generation Controversy*, pp. 18-19, 21, and *passim*.

151. Leeuwenhoek to Nehemiah Grew, 25 April 1679, in Leeuwenhoek, *A.d.B.*, III, 18-19; Leeuwenhoek to Lambert van Velthuysen, *ibid.*, pp. 78-81.

152. Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, V, 263-265.

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arose in the testicles through some process essentially akin to the generation of true animals. Among the spermatozoa that he had first observed in animal testicles (or more precisely, in this instance, in a rooster's epididymis) he had also seen oval particles. These he suspected might be immature spermatozoa that, not yet endowed with life, lay rolled up like the unborn young he had discovered in the bodies of vinegar eels.¹⁵³ In subsequent years he recounted similar observations of globules and other particles that he also took for developing or immature spermatozoa – in the case of the globules, still curled up like the unborn young in the womb.¹⁵⁴ He found no spermatozoa but only globules in the testicles of immature rams, and the younger the animal the smaller the globules,¹⁵⁵ which he presumably interpreted in the light of earlier thoughts about the *zaad* of the spermatozoa lying dormant until the animal's more mature years.

In 1680 such globules had already suggested to Leeuwenhoek that the spermatozoa came from eggs and propagated themselves (*voor teelden*) in the filaments of the testicle, and thirty-six years later he assured Boerhaave that this was so, since the great quantity of spermatozoa released by a vigorous animal over the course of a year could not have all been once enclosed together within the constricted space of the testicles.¹⁵⁶ To explain the replenishment of spermatozoa for the milt of fish, he proposed that a few spermatozoa remained in the testes of the fish to produce new spermatozoa, which were then, with their parents, ready to produce more of their kind in as little perhaps

153. Leeuwenhoek to Nehemiah Grew, 25 April 1679, *ibid.*, III, 16-19.

154. Leeuwenhoek to Robert Hooke, 5 April 1680, *ibid.*, pp. 202-205; Leeuwenhoek to the Royal Society, 9 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 100; Leeuwenhoek to Hans Sloane, 25 December 1700, *ibid.*, p. 298; Leeuwenhoek to James Petirer, 18 August 1711, Leeuwenhoek Letters, Royal Society Library, London, EL.L4.38, fols. 140^v-141^v; Leeuwenhoek to Herman Boerhaave, 5 November 1716, in Leeuwenhoek, *Send-Brieven*, p. 286; Leeuwenhoek to Herman Boerhaave, 21 November 1716, *ibid.*, p. 310.

155. Leeuwenhoek to James Petirer, 18 August 1711, Leeuwenhoek Letters, Royal Society Library, London, EL.L4.38, fols. 140^v-141^v.

156. Leeuwenhoek to Robert Hooke, 5 April 1680, in Leeuwenhoek, *A.d.B.*, III, pp. 204-205; Leeuwenhoek to Herman Boerhaave, 5 November 1716, in Leeuwenhoek, *Send-Brieven*, p. 286. However, in 1716 Leeuwenhoek reported finding no developed spermatozoa in the testicles themselves of a ram, though he claimed to have found spermatozoa in various stages of development in the epididymis. (Leeuwenhoek to Herman Boerhaave, 21 November 1716, *ibid.*, pp. 309-310.)

as twenty-four hours; since in the course of a year this replenishment numbered in the millions, according to Leeuwenhoek, it was a phenomenal propagation indeed, but he readily recalled the surprising multiplication he had observed among other microscopic creatures.¹⁵⁷

At least one reader of Leeuwenhoek's letter to Boerhaave took Leeuwenhoek's meaning to be that the spermatozoa propagated in the testicles *juxta leges procreations* [*sic*],¹⁵⁸ but it was apparent that the "laws" of normal animal procreation as then perceived could not be applied to the spermatozoa without encountering further difficulties. Challenging Leeuwenhoek's basic contention about the role of the spermatozoa in generation, Martin Lister had raised the issue of their origin in the *Philosophical Transactions* of 1698.¹⁵⁹ Lister assumed correctly that since Leeuwenhoek would hardly accept the spontaneous generation of the spermatozoa, he could only believe that they reached maturity and acquired the capacity to reproduce themselves while in the semen. But this was absurd, argued Lister, for the same animal would mature (*adolescere*) twice, once in the semen and again *in humano statu atque conditione*. Inevitably someone – Leeuwenhoek's countryman Pierre Lyonet, later in the eighteenth century, if no one else – would protest as well that if the spermatozoa reproduced themselves in the semen, they would have to have, according to Leeuwenhoek's own principles, infinitely smaller animals in their own semen, which in turn would have other animals proportionally smaller, and thus to infinity.¹⁶⁰ Lister's argument had altered his opinions not a jot, Leeuwenhoek had in the meantime responded,¹⁶¹ but it did apparently inspire him to derive a model for the propagation of the spermatozoa from other recent observations – observations that should have called the role of the spermatozoa in animal generation even more directly into question.

157. Leeuwenhoek to Herman Boerhaave, 5 November 1716, in Leeuwenhoek, *Send-Brieven*, pp. 287-290.

158. See the summary of Leeuwenhoek's letter of 5 November 1716 to Boerhaave published in Belloni, "Leeuwenhoek, Boerhaave e Bleyswyk," p. 332.

159. Martin Lister, "An Objection to the New Hypothesis of the Generation of Animals from *Animalcula in Semine Masculino*," *Phil. Trans.*, 244 (September 1698), p. 337.

160. Pierre Lyonet, annotation in *Theologie des insectes* by Friedrich Christian Lesser, trans. Lyonet (Paris: Hugues-Daniel Chaubert & Laurent Durand, 1745), I, 245.

161. Leeuwenhoek to the Royal Society, 23 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 102.

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Leeuwenhoek had in fact observed side by side in the semen what he took to be two kinds of differently shaped spermatozoa, which he remained convinced were males and females.¹⁶² Although he also observed spermatozoa clinging together as if (*even of*) in the act of mating,¹⁶³ he was inclined to believe not that the spermatozoa engaged in sex among themselves but rather that the male spermatozoa became male animals and the female spermatozoa, females.¹⁶⁴ He suggested in 1699 that when the spermatozoa left the testicles, they left behind a "seminal stuff" (*zaadelijke stoffe*) from which their kind (*geslacht*) could come, and they did this without mating, he emphasized, as did other small animals he had now directly observed – animals, moreover, that continued to grow after bearing their young and that changed eventually into flying creatures.¹⁶⁵ This was his answer to Lister, and it rested on his discovery of the parthenogenetic generation of aphids.

Four years before, in 1695, Leeuwenhoek had described with amazement the rudimentary beginnings and even the recognizable bodies of the next generation that he had found within very young aphids.¹⁶⁶ Born living from their mother's body, the young aphids grew some, bore many new young themselves – without mating or males, he added in 1700 – then changed into flying creatures – that looked like a different animal to the naked eye, he also later stressed, doubtless for Lister's sake – and produced young again.¹⁶⁷ After

162. Leeuwenhoek to Christopher Wren, 22 January 1683, in Leeuwenhoek, *A.d.B.*, IV, 10-11; Leeuwenhoek to the Royal Society, 30 March 1685, *ibid.*, V, 180-183; Leeuwenhoek to the Royal Society, 23 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 107; Leeuwenhoek to Gottfried Wilhelm Leibniz, 17 November 1716, in Leeuwenhoek, *Send-Brieven*, p. 299.

163. Leeuwenhoek to the Elector Palatine, 18 September 1695, in Leeuwenhoek, *Vijfde Vervolg*, pp. 145-146.

164. Leeuwenhoek to the Royal Society, 30 March 1685, in Leeuwenhoek, *A.d.B.*, V, 180-183; Leeuwenhoek to Gottfried Wilhelm Leibniz, 17 November 1716, in Leeuwenhoek, *Send-Brieven*, p. 299.

165. Leeuwenhoek to the Royal Society, 23 June 1699, in Leeuwenhoek, *Sevende Vervolg*, p. 106.

166. Leeuwenhoek to Frederik Adriaan, Baron van Reede, 10 July 1695, in Leeuwenhoek, *Vijfde Vervolg*, pp. 90, 100. Regarding Leeuwenhoek's observations of aphids, see F. J. Cole, "Microscopic Science in Holland in the Seventeenth Century," *J. Quekett Micros. Club*, ser. 4, 1 (1938), 61-64; A. Schierbeek, *Antoni van Leeuwenhoek, zijn Leven en zijn Werken* (Lochem: "De Tijdstream," 1950-1951), I, 271-278.

167. Leeuwenhoek to Frederik Adriaan, Baron van Reede, 10 July 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 90; Leeuwenhoek to Hans Sloane, 26 October 1700, in Leeuwenhoek, *Sevende Vervolg*, p. 283.

Lister's challenge, Leeuwenhoek seized upon this extraordinary pattern of generation as an analogue for the propagation of the spermatozoa.¹⁶⁸ Just as the aphids still in their mother's body were already endowed with a seminal stuff, he wrote in 1700, so the spermatozoa left behind them in the testicles either some animalcules or a seminal stuff from which their own kind would again be produced – like the aphids, without mating.¹⁶⁹ Moreover, seeing that the aphids changed from walking into flying creatures after having produced so many young, it was possible too that the spermatozoa, having left that seminal stuff behind, assumed in the uterus the form of the larger animal.¹⁷⁰ This change would remain unseen “because of smallness and compactedness [*in een geschiktheid*],” but having witnessed such propagation and change in the aphid should be enough, he concluded.

Lister had been answered (and Lyonet's future cavil unknowingly nullified), although the emphasis on generation by mothers and daughters without mating or males would seem to have implicitly raised a greater, if unacknowledged, problem for Leeuwenhoek's doctrine of the spermatozoa.¹⁷¹ Moreover, the origin of the very first spermatozoa in each male animal remained obscure. More intensive studies of aphid

168. Leeuwenhoek spoke of the reproductive cycle of the aphids as the most astonishing instance of propagation he had seen (Leeuwenhoek to Frederik Adriaan, Baron van Reede, 10 July 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 90), unique, as far as he knew, to this insect. (Leeuwenhoek to Hans Sloane, 26 October 1700, in Leeuwenhoek, *Sevende Vervolg*, pp. 282-283.) However, see also note 171 below.

169. Leeuwenhoek to Hans Sloane, 26 October 1700, in Leeuwenhoek, *Sevende Vervolg*, p. 282.

170. *Ibid.*, p. 283. F. J. Cole concluded that Leeuwenhoek looked upon the aphids themselves as spermatoc animals. (Cole, “Microscopic Science in Holland,” p. 64.) Against the background of Lister's letter, however, the analogy between the generation of aphids and spermatozoa would seem to have been intended more as a model for the latter than an explanation of the former.

171. Leeuwenhoek assumed an absence of males and mating in a few other species as well. See Leeuwenhoek to the Royal Society, 10 July 1696, in Leeuwenhoek, *Sesde Vervolg*, p. 272; Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 240^r; Leeuwenhoek to the Royal Society, 21 March 1704, *ibid.*, EL.L3.62, fols. 284^r-284^v; Leeuwenhoek to Cornelis Spiering, 22 May 1716, in Leeuwenhoek, *Send-Brieven*, p. 218; Leeuwenhoek to the Royal Society, 22 September 1711, Leeuwenhoek Letters, Royal Society Library, London, EL.L4.40, fol. 153^v; Leeuwenhoek to Herman Boerhaave, 5 November 1716, in Leeuwenhoek, *Send-Brieven*, p. 288; Leeuwenhoek to James Jurin, 1 May 1722, Leeuwenhoek Letters, Royal Society Library, London, EL.L4.69, fol. 273^r.

generation later in the century would be perceived as enhancing the case for preexistence.¹⁷² and Leeuwenhoek also saw in his own observations added testimony, at least, that all living things derived from those created in the beginning.¹⁷³

Relentless in his denial of spontaneous generation, he insisted on a continuous, unbroken linkage between the successive generations of every species since the creation of the world, a linkage physically embodied in the stuff (*stoffe*) in the spermatozoon or seed from which the next generation of spermatozoa or seeds would arise.¹⁷⁴ He did not speculate in his letters on the nature of that stuff, however, or of the *zaad* (presumably the same) from which he was very early convinced the spermatozoa came. In his letters, consequently, the ultimate mechanisms by which the intricate structures (and instincts)¹⁷⁵ of animals were preserved or repeatedly and faithfully reconstructed remained a mystery, and a hopelessly impenetrable one at that. "In sum," he wrote in 1685, "the smallness from which a man is produced from generation to generation is incomprehensible."¹⁷⁶ Indeed, "the first essential stuff [*eerste wesentlijke stoffe*], or the beginning from which a man is produced (which, to us, is incomprehensibly small),

172. See John R. Baker, *Abraham Trembley of Geneva, Scientist and Philosopher, 1770-1784* (London: Edward Arnold, 1952), p. 183; Roger, *Les Sciences de la vie*, pp. 381-382.

173. Leeuwenhoek to Frederik Adriaan, Baron van Reede, 10 July 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 90.

174. Leeuwenhoek to the Royal Society, 13 July 1685, in Leeuwenhoek, *A.d.B.*, V, 264; Leeuwenhoek to the Royal Society, 24 August 1688, *ibid.*, VII, 378-380.

Stoffe has been translated as "substance" in these passages in *A.d.B.* and might also have been translated as "matter," but I have avoided these terms because in the context of the seventeenth century they are too redolent of formal philosophic currents of thought that remained alien to Leeuwenhoek's thinking. He did speak at least once, however, of the *wesen* (*wezen*) – "essence," "substance," "nature," or "being" – that was one of the components poured into – or perhaps, after all, made within – the developing fruit and from which came the beginning of the embryo plant in the seed. (Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, V, 266.)

175. See Leeuwenhoek to Frederik Adriaan, Baron van Reede, 20 August 1695, in Leeuwenhoek, *Vijfde Vervolg*, p. 135; Leeuwenhoek to Antonio Magliabechi, 16 October 1699, in Leeuwenhoek, *Sevende Vervolg*, pp. 149-150.

176. Leeuwenhoek to the Royal Society, 13 July 1685, in Leeuwenhoek, *A.d.B.*, V, 264-265.

will remain hidden and inscrutable," as would as well the stuff that was the beginning of the embryo plant within the seed.¹⁷⁷

Having reached the limits of his imagination – and passed far beyond those of his microscopes – Leeuwenhoek readily acknowledged that such inquiries ended in ignorance, for he believed this ignorance to be inescapable and insuperable. Continuing explorations with his microscopes had confirmed nature's ultimate mysteriousness, if only because of the incomprehensible and impenetrable smallness into which nature seemed everywhere to recede.¹⁷⁸

Presumably what that smallness concealed was essentially structure. Leeuwenhoek did believe that oozing fluid could produce such elemental forms of organic construction as globules and even vessels,¹⁷⁹ but reflections on the formation of the embryo plant in the seed reemphasized his intuitive conviction that the organized structure of a living thing could arise only from a correspondingly intricate structure. He wrote not only that the embryo plant was made in the seed, but that it came to the seed through the seed stalk,¹⁸⁰ and he asserted in 1696 that the stalk of the nutmeg seed had to contain every vessel that was in the tree, for otherwise the stalk could not impart to the embryo all the vessels the tree (and its fruit) would need.¹⁸¹ In short, he concluded with a familiar emphasis, the perfection that lay inclosed not only in every seed but in every seed stalk was incomprehensible and inscrutable. One step before the formation of the embryo plant, he had implicitly excluded the prospect of preexistence, but he still explicitly

177. *Ibid.*, pp. 266-267. Regarding seeds see also Leeuwenhoek to the Royal Society, 24 August 1688, *ibid.*, VII, 378-381.

178. See also Leeuwenhoek to the Royal Society, 12 August 1692, in Leeuwenhoek, *Derde Vervolg*, p. 492; Leeuwenhoek to Hans Sloane, 25 December 1700, in Leeuwenhoek, *Sevende Vervolg*, p. 306; Leeuwenhoek to the Royal Society, 21 June 1701, *ibid.*, p. 360; Leeuwenhoek to the Royal Society, 22 September 1711, Leeuwenhoek Letters, Royal Society Library, London, EL.L4.40, fol. 147^v; Leeuwenhoek to Abraham van Bleyswyk, 2 March 1717, in Leeuwenhoek, *Send-Brieven*, p. 316.

179. Leeuwenhoek to Robert Hooke, 3 March 1682, in Leeuwenhoek, *A.d.B.*, III, 414-415; Leeuwenhoek to the Royal Society, 14 May 1686, *ibid.*, VI, 50-51.

180. Leeuwenhoek to the Royal Society, 13 July 1685, *ibid.*, V, 238, 240-241; Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 233^v.

181. Leeuwenhoek to Nicolaas Witsen, 8 March 1696, in Leeuwenhoek, *Sesde Vervolg*, p. 243. See also Leeuwenhoek to the Royal Society, 26 February 1703, Leeuwenhoek Letters, Royal Society Library, London, EL.L3.51, fol. 234^r.

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assumed the necessity of a structure that reflected all the details of the future plant.

A mechanistic bias toward the primacy and continuous necessity of structure in living processes often molded Leeuwenhoek's interpretation of the strange new images he confronted through the microscope, but those images in turn crystallized that bias into specific conjectures and convictions. The interplay between images and preconception was often so immediate that the initial perception and subsequent speculation cannot be disentangled. The observation not of new microscopic "animals" but of what he took to be complex structure within the semen first convinced Leeuwenhoek of the semen's preeminent role in generation, but his reading of whatever it was he saw as a tangle of vessels suggests a readiness, at least, to discover some such structural rudiments, a readiness that would have been characteristic of the times. The vessels within the embryo plant were a mistaken perception, but an obvious one nonetheless; for it conformed, like the vessels in the semen, to the most immediate and simplistic mechanistic inference concerning generation, that the organized structure simply endured.¹⁸²

Leeuwenhoek's observations of the spermatozoa themselves offered a particularly flagrant example of a simple image exploited by preconceptions. The very motion of the spermatozoa argued that they possessed all the parts and complexity that seventeenth-century mechanism demanded for any living and moving animal, and when the presence of the spermatozoa in the testicles revealed to him their truly seminal nature, those parts and that complexity answered perfectly to his expectation of a preformed structure in generation: one mechanistic presumption neatly confirmed another.¹⁸³

Nonetheless, Leeuwenhoek appears never to have accepted the primeval preexistence of each individual plant or animal, although late seventeenth-century mechanism was incapable of conceiving how such intricate structures as even the complexity of vessels Leeuwenhoek imagined in the seed stalk could successively engender themselves from generation to generation, passing on the continuing capacity to produce the organism dictated in their construction. Where his microscopes no

182. Malebranche noted that the transformation of the egg into a chick was infinitely more difficult than the preservation of a chick that was already entirely formed. (Malebranche, *La Recherche de la vérité*, in *Oeuvres complètes*, II, 105.)

183. Leeuwenhoek to Herman Boerhaave, 26 August 1717, in Leeuwenhoek, *Send-Brieven*, pp. 404-405.

longer offered suggestive and seemingly concrete images to give more specific shape to his vague mechanistic expectations, Leeuwenhoek simply declined to conjecture further and settled for the indefiniteness of an antecedent or seminal "stuff." Although it is doubtful that Leeuwenhoek would ever have knowingly insisted that nature had to adhere to the mechanistic preconceptions of his age, his final emphasis on the incomprehensibility of generation does not argue that he had succeeded in freeing himself from such preconceptions. That incomprehensibility was ascribed, after all, not to nature's indifference to the seeming imperatives of structure and moving parts, but to an impenetrable smallness that cast an unyielding veil over nature's ultimate *modi operandi*.