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"ova vel semina … foecundare". Sexual Reproduction in Leibniz's Scientific Correspondence

1. Introduction

The quotation in the heading is taken from Leibniz's reply of 23 April 1701, entitled *Epistola responsoria de methodo botanica*[1], to an open letter of 14 April 1701 addressed to him by the physician Alexander Christian Gakenholz with the title *Epistola … de emendanda ac rite instituenda medicina*[2]. Both have been published recently in volume 8 of Leibniz's Mathematical, Scientific and Technical Correspondence (A III, 8). Leibniz's *Epistola responsoria* has also appeared recently in English under the title *On Botanical Method (1701)* in Justin E. H. Smith's *Divine Machines. Leibniz and the Sciences of Life*[3]. This paper will explore Leibniz's thought on sexual reproduction in the vegetable and animal kingdoms as revealed in his correspondence with Gakenholz in 1701. A central issue in these discussions was the theory of preformation and the contending views of animalculists and ovists. One of the most prominent animalculists was the Dutch microscopist Antoni van (Van) Leeuwenhoek (1632-1723) who Leibniz had visited In Delft in November 1676. Leibniz's correspondence with him almost 40 years later (in 1715-1716) is therefore of special significance. The physiological topics discussed in the Leibniz-Leeuwenhoek correspondence include the sexual reproduction of mammals and other animate beings as well as the theory of preformation.

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[1] A III,8 N. 253.
[2] A III,8 N. 241.
[3] Justin E. H. Smith: *Divine Machines . Leibniz and the Sciences of Life*, Princeton / Oxford 2011. See Appendix 5.

2. The year 1701

In the spring of 1701 Leibniz's correspondence with Alexander Christian Gakenholz gained a special significance, particularly in the fields of biology and medicine. Following a discussion with Leibniz (probably in March 1701) Gakenholz composed an open letter addressed to him dated 14 April 1701 with the title *Ad illustrem atque excellentissimum virum Dominum Godefr. Guilielmum Leibnitium . . . epistola . . . de emendanda ac rite instituenda medicina*. The first printed version of this epistola[4] was sent as an enclosure to Gakenholz's letter to Leibniz dated 21 April 1701[5]. The correspondent attributes the inspiration for his composition to his discussion with Leibniz a few weeks earlier:

> "Ich bin, wie ich vor einigen Wochen die Ehre gehabt deroselben meine reverence zu machen, durch dero de re medica et imprimis herbaria gegen mir geführte gelehrte discourse auf einige Gedanken gekommen, welche in beygehender kleinen dissertation kürtzlich entworfen, um solche Ew. Excellence scharfsinnigen Urtheil zu unterwerfen."

Also, in the month of April 1701 there appeared a summary and review of Gakenholz's *epistola* in the *Monatlichen Auszug*[6]. In this review the writer (perhaps J. G. Eckhart) outlined Gakenholz's criticism of the existing system of medical studies. At the core of studies, according to Gakenholz, should be anatomy, the science dealing with the structure of plants, animals and the human body which was to be considered as a machine or automaton. The heart was the prime mover of the machine and anatomy served the purpose of the meticulous study of the vessels emanating from the heart in their natural state. Thus, the circulation of the blood would be revealed and, for example, the passage of blood from the heart through the largest artery, the aorta, and then through the body to the kidneys illustrated:

> "Wenn … der Menschliche Leib aber eine Machine oder Automaton sey, so müsse man erstlich nothwendig dieselbe und wie sie zusammengesetzt sey, wohl inne haben; welches durch die Anatomie geschehe. Diese müsse … nach der natürlichsten methode gehen, vom Hertzen als primo mobili, daraus alle Gefässe fliessen, anfangen: die daraus rinnende Gefässe verfolgen und sorgfaltig examiniren: Wenig in stücken schneiden und alles nach möglichkeit in seinen natürlichen stande lassen. Auf diese weise würde man erkennen wie die theile zusammen hangen und z. e. sehen, wie das Blut aus den struncke der grossen Arterie durch die emulgentes in die Nieren komme."

The blood and other body fluids were the focus of the anatomy of fluids and here experimental science, and particularly chemistry, had a special role to play. Aspirants in the field of chemistry ought to be mainly concerned with the subject as revealed in the works of nature with, for example, the chemical reactions of life, and the seat of most illnesses, being found in body fluids:

> "Das andre theil des Menschlichen Leibes machen die partes fluidae das Blut und serum

[4] E^1 of A III,8 N. 241.
[5] A III,8 N. 252.
[6] E^2 of A III,8 N. 241.

wie auch die spiritus animales vornemlich aus, als aus deren constitution die meisten kranckheiten fliessen. Daher die Anatomia fluidorum sehr nöthig, aber auch sehr schwer sey, weil sie nicht mit den Augen, sondern durch allerhand experimenta und die Chymie müste erkandt werden. Denn wer die Chymie studieren wolle, müsse hauptsächlich durch sie die Natur in ihren wercken, der Natürlichen dinge erzeugungen, vernichtungen und veränderungen und deren uhrsachen erlernen."

Besides anatomy and chemistry, botany too had a particular significance. A special desideratum in this area was the development of a taxonomy or classification system on the basis of parts of plants such as flowers, fruit, seeds or roots.

From Leibniz's reply of 23 April 1701[7] it is evident that Gakenholz had picked out and developed suggestions introduced by Leibniz at their meeting some weeks earlier including thoughts about the taxonomy or classification of plants. A further influence on Leibniz's thought in relation to the classification of plants was no doubt the letter sent to him by Johann Heinrich Burckhardt on 21 February 1701 from Wolfenbüttel[8] following a meeting between the two a few days earlier. No immediate response to Burckhardt's letter has been found but from Leibniz's letter to Gakenholz of 23 April 1701 it is evident that a classification of plants according to a single criterium such as the form of flowers, fruit, seeds or roots was for him insufficient. Combinatorics, and in particular Leibniz's own dissertation on the combinatorial art viz. the *Dissertatio de arte combinatoria* of 1666, appeared to offer a way forward. In addition to mathematics, philosophical and juridical categories also seemed to have a significance for the development of botanical systematics and classification. For Leibniz however further progress seemed to depend above all on improved knowledge of the inner workings of these machine-like entities. Organic bodies produced by nature like plants and animals represented machines for the fulfillment of certain duties and functions such as nutrition, reproduction and the preservation and perpetuation of knowledge:

"Plantae et animalia et, ut verbo dicam, Organica corpora, quae natura producit, sunt Machinae ad perpetuanda quaedam munia aptatae, quod faciunt tum propagatione speciei tum nutrimento individui … Et humanum quidem corpus manifestum est machinam esse aptatam ad contemplationem perpetuandam."

Just as one differentiated between theoretical and practical mathematics one ought to distinguish between theoretical biology, on the one hand, and practical biology and medical practice on the other hand. To theoretical biology belonged the classification of plants according to one or several criteria.

Leibniz had long been interested in the animate beings of earlier epochs and in the science of these creatures. In 1696 and 1697 for example he obtained intelligence on a trove of bones in Gräfentonna[9]. In his letter to Gakenholz on 23 April 1701 Leibniz employs concepts from the field of comparative anatomy (such as "collatio animalium") and from developmental biology

[7] A III,8 N. 253.
[8] A III,8 N. 213.
[9] i. e. Tonna in the territory of Thuringia; see A I,12 N. 357 and A III,7 N. 70. See also James G. O'Hara: *The Irish elephant, the whale penis and the child born with two heads. Animal and human autopsies in Leibniz's correspondence*, in: *Natur und Subjekt, IX. Internationaler Leibniz-Kongreß.* Vorträge 2. Teil, Ed. Herbert Breger et al., Hannover, 26. September –1. Oktober 2011, pp. 777-783.

(like "plantarum cum animalibus connexio" or "transitus per intermedia"). Here he speaks of a link between plants and animals on the common basis of respiration, or respiratory organs, and of insects as an intermediate form between plants and animals, particularly with Jan Swammerdam's *Historia insectorum generalis* (1669) in mind:

> "Sed quemadmodum collatio animalium etiam in aliis partibus utiliter adhibetur uti Anatomia comparativa ostendit, usque adeo ut in pulmonibus potissimum vel respirationis organis reperta sit plantarum ipsarum cum animalibus connexio ac series quaedam, et velut transitus a plantis ad animalia majora per intermedia, ut sic dicam, insecta Swammerdamii monitu."

Leibniz's main focus in all of this was however for the establishment of a classification system of plants. Of particular importance for a comparison and classification of plants were the sexual organs of flowering or seed-producing plants. In addition, sexual reproduction represented a connecting element between the vegetable and animal kingdoms. Leibniz explains that the mode of fertilization in seed plants is one in which pollination is mediated through pollen tubes (i. e. by means of siphonogamy). With mammals male-female intercourse and fertilization occur in analog fashion through copulation by means of analogous organs. The pollen of seed-producing or flowering plants corresponds to mammalian sperm. Similarly, the style of a flower corresponds to the vagina in placental mammals and the ovary at the bottom of the style corresponds to the mammalian ovary. Fertilization occurs following pollination when a kind of spirit coming from the pollen penetrates the ovary where either the egg or the seed is duly fecundated:

> "Novam etiam et magni inprimis momenti futuram comparationem Plantarum suppeditabunt novae ... Observationes de duplicis sexus imitamento in plantis ... Nam in polline subtilissimo florum quaerunt masculi seminis analogiam negantque hujusmodi aliquid in ulla planta desiderari … Adesse excipiendo pollini capsulas ovario foemineo comparandas: A capsula exire stylum vel analogum aliquid tanquam uteri vaginam: Cujus ad summitatem ex flore per solis calorem aperto, concutientis venti ministerio, se transferat applicetque pollen: Ex pollinis autem granulis spirituosum aliquid perductum ad ovarium, ut sic dicam, vel siliquam penetrare, atque ova vel semina illic foecundare."

In this context Leibniz recalled the rival theories of preformation of the Dutch microscopist Antoni van Leeuwenhoek and of his compatriot the anatomist Theodor Kerckring. In the ovist-animalculist controversy Leibniz saw here a possible reconciliation. His own position however was close to that of the animalculist Leeuwenhoek and removed from that of the ovist Kerckring. The preformist theory assumed that the entire organism was preformed either in the sperm (the animalculst position) or the egg (the ovist position) and had only to unfold or deconvolve itself in the process of fertilization. Here again Leibniz saw a connection between the vegetable and animal kingdoms:

> "Quae si observatione porro comprobabuntur, magis firrmabunt conciliationem Kercringianae atque Leewenhoekianae doctrinae; quae mihi semper verisimillima visa est. Nempe subtile aliquid dudum organicum, quod jam plantae vel animalis nomine censeri possit, ex masculo semine in foeminea ova pervenire, atque illic tanquam in propria terra transformatum et nutrimento in majus elaboratum generationis nomine in foetum prodire."

3. Prior to 1701

Long before 1701 Leibniz was well informed about Leeuwenhoek's observations with the microscope and particularly those concerning the theory of preformation. Thus, his correspondent Johann Georg Graevius at the University of Utrecht informed him on 24 March 1679 about Leeuwenhoek's discovery of amimalcula in human semen (also called "spermatic amimalculae" in medical literature) referring to the latter's article in the *Philosophical Transactions* entitled "Observationes de natis e semine genitali animalculis" [10]. Thus Graevius writes[11]:

> "In Physicis et Mathematicis vix quicquam memorabile hic nuperius inventum, nisi quod Delfis sit, qui mirabilia animalcula et infinita in sanguine et semine humano detexit subsidio microscopii accuratissimi, de quibus observationibus extant quaedam epistolae ad societatem Anglicam exaratae Anglice."

In his correspondence with Antoine Arnauld in the mid and late 1680s Leibniz refers to the discoveries of Leeuwenhoek and to the theory of preformation. Thus, on 8 December 1686 he writes to this correspondent that the creation of an animal represented merely a transformation of an already existing animal. The subsequent demise of the creature was likewise a further transition into yet another state[12]:

> "… comme il se peut que selon les sentimens de M. Leewenhoeck toute generation d'un animal, ne soit qu'une transformation d'un animal déja vivant, il y a lieu de croire aussi, que le mort est n'est que une autre transformation".

Again, in September 1687, Leibniz refers specifically to the theory of preformation and the interpretation of Jan Schwammerdam and Leeuwenhoek[13]:

> "les experiences rendent assez probable, que tout animal estoit déja organisé, bien qu'il fust imperceptible. Et plusieurs habiles homes particulierement Messieurs Schwammerdam et Leewenhoek (qui valent bien d'autres en ces matieres) ont penché de ce costé là."

Finally, on 9 October 1687, Leibniz tells Arnauld of his penchant for the interpretation of the Dutch scientists[14]:

> "J'ay appris depuis quelque temps que M. Leewenhoeck a des sentimens assez approchans des miens, en ce qu'il soutient que même les plus grands animaux naissent par une maniere de transformation, je n'ose ny approuver ny rejetter le detail de son opinion, mais je la tiens tres veritable en general, et M. Swammerdam autre grand observateur et Anatomiste, temoigne assez qu'il y avoit aussi du penchant. Or les jugemens de ces Messieurs là valent ceux de bien d'autres en ces matieres."

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[10] *Philosophical Transactions*, N. 142, December 1677-February 1678, pp. 1040-1043.
[11] See A III,2 N. 433, p. 448 and annotation .
[12] See A II,2 N. 24, p. 115.
[13] See A II,2 N. 56, p. 235.
[14] See A II,2 N. 57, p. 254f.

In Leibniz's epistolary exchanges in the 1690s with correspondents in the Netherlands the theory of preformation and the competing interpretations of the animalculists and ovists are clearly in evidence. In a letter of 2 August 1698 to Leibniz the mathematician Johann Bernoulli in Groningen refers to the rival interpretations of the animalculists (like Leeuwenhoek) and of the ovists (attributed to William Harvey – author of *Exercitationes de generatione animalium* (1651) – and others) [15]:

> "secundum Harvaeum et alios sed non secundum Leuwenhoeck in animali innumera sunt ovula, in quolibet ovulo animalculum vel plura, in quolibet animalculo (faemella) iterum innumera ovula et ita in infinitum."

In correspondence with the influential Burgomaster or Mayor of Delft Hendrik Van (van) Bleiswijk between 1697 and 1699 Leibniz repeatedly enquired about the work and welfare of Leeuwenhoek. Some of Leibniz's letters to Bleiswijk were shown to Leeuwenhoek so that this exchange represents an indirect correspondence between the two. In a letter of 6 January 1699 to the Burgomaster Leibniz refers to a recent discovery of Leeuwenhoek concerning the origin and reproduction of animals but which transcended the aspect of the vermicular beings he had previously discovered in semen[16]:

> "On me dit que Mons Leewenhoek a decouvert je ne sçay quoy de nouveau depuis peu, touchant l'origine des animaux, car je ne parle point des petits vers de la semence, dont il avoit deja donné connoissance au public."

Yet another influence on Leibniz's thought at this juncture may have been Martin Lister's article in the *Philosophical Transactions* entitled "An objection to the new hypothesis of the generation of animals from animalcula in semine masculino." [17]

4. After 1701

Following the correspondence with Gakenholz in 1701 Leibniz continued to refer to the theory of preformation in his learned correspondence. Thus, in a letter to the queen Sophie Charlotte and John Toland of early December 1702 Leibniz explains his views on preformation[18] referring to Swammerdam's *Historia Insectorum Generalis* (1669) and and to Leeuwenhoek's (previously cited) article "Observationes de natis e semine genitali animalculis" (1677/78):

> "Et les experiences de fort habiles observateurs, particulierement de Messieurs Swammerdam et Leewenhoeck, tendant à nous faire juger, que ce que nous appellons la generation d'un animal nouveau, n'est qu'une transformation developpée par l'accroissement d'un animal deja formé, et qu'ainsi la semence animée et organisée est aussi ancienne que le monde."

Leibniz also refers to Leeuwenhoek, and confesses his penchant for the latter's

[15] See A III,7 N. 212, p. 847f.
[16] See A I,16 N. 260, p. 403f. and annotation.
[17] *Philosophical Transactions* , N. 244, September 1698, p. 37.
[18] See A I,21 N. 410, p. 722f. and annotation.

interpretation of theory of preformation, in his philosophical writings between 1704 and 1714, particularly in the *Theodicy* (Preface and § 90f.), *Monadology* (§ 73-76) and in the *Nouveaux Essais*. In the latter work Leibniz expresses the view that Leeuwenhoek had enhanced the status of the male sex, and accordingly degraded the female sex which merely provided a nutrient medium for the seed[19]:

> "Mr Leewenhöeck a rehabilité le genre masculin et l'autre sexe est degradé à son tour, comme s'il ne faisoit que la fonction de la terre à l'egard des semences, en leur fournissant le lieu et la nourriture."

5. The years 1715-1716

Leibniz finally entered into correspondence with Leeuwenhoek on 5 August 1715. The publication of the ovist Antonio Vallisnieri entitled *Nuove osservazioni, ed esperienze intorno all'ovaja scoperta ne' vermi tondi dell'uomo, e de' vitelli* at Padua in 1713 was probably the inspiration for Leibniz's report that the Italian author did not accept the fact that animals were preformed in the animalcula or little animals – observed by Leeuwenhoek himself in animal semen – but maintained rather that the future animal was already present in the egg and only needed to be awakened by the stimulus of conception[20]:

> "Es gibt mir aber dieses gelegenheit zu schreiben daß ein sehr gelehrter und erfahrner Mann zu Padua, nahmens H. Vallisnieri nicht zulaßen will, daß die thierlein die Mein Herr in dem Saamen der thiere sichtbar machet, die jenigen seyn durch deren Veränderung und Wachsthum die großen thiere selbst entstehen, sondern es scheinet er meyne das thier stecke schohn im Ey, und werde durch die empfangniß nur erwecket. Er hat vor ein werck daruber heraußzugeben[,] hat aber … schohn in seinen gedruckten schrifften etwas davon gedacht. Mir ist meines Herrn meynung zimlich wahrscheinlich vorkommen … Und ich habe auch in Meiner Theodicaea solches erwehnet[.]"

In his reply of 28 September 1715 Leeuwenhoek presents himself as an undoubting animalculist.[21] In his view, Vallisnieri failed to accept the essential role played by the animalcula, the little animals in mammalian semen, and considered instead that animals preexisted in the egg and were simply imbued with vitality in the act conception. In Leeuwenhoek's view, the supporters of his interpretation far outnumbered opponents like Vallisnieri. His proponents included not only Leibniz but figures like Herman Boerhaave, the influential professor in Leiden who has publicly acclaimed the validity and widespread acceptance in Europe of the Leeuwenhoekian theory of sexual reproduction:

> "Aus Ihrem liebenswürdigen Brief … ersehe ich, daß der hochgelehrte Herr Vallisnieri

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[19] See A VI,6, p. 316f.
[20] LBr. 538, 1; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.
[21] Antoni van Leeuwenhoek, *Send-Brieven … over verscheyde Verborgentheden der Natuure*, Delft 1718; Antoni van Leeuwenhoek, *Epistolae Physiologicae super complures Naturae Arcanis*, Delft 1719; Antoni van Leeuwenhoek, *Opera OmniA* IV *Epistolae Physiologicae*. Hildesheim: Georg Olms, 1972; see *Epistola* XVIII, pp. 164-169. Also K. Meyer (Transl.), *Send-Brieven … Aus dem Lateinischen übersetzt und kommentiert durch Dr. Klaus Meyer Soest* (ca. 1995), Gottfried Wilhelm Leibniz Bibliothek, Hannover, Shelf mark: Leibn. 2363; see *Sendbrief* 18, pp. 122-126 and p. 233.

aus Padua mir in der Sache der von mir entdeckten Animalcula im tierischen Samen nicht zustimmt.
Er glaubt nicht, daß die Tiere aus den Samen hervorgehen den herkömlichen Veränderungen unterliegen und heranwachsen. Vermutlich meint er, daß das Animalculum schon im Ei existiere und durch den Reiz der Empfängnis zur vitalen Bewegungsfähigkeit geweckt werde … Wenn der Herr Vallisnieri mir entgegen steht, so habe ich dem tausend Mitstreiter entgegen zu setzen.
Sie werden hinzunehmen, daß meine Meinung viel Wahrscheinlichkeit für sich hat und nicht wenig bei Ihnen gilt, wie Sie es in Ihrem Buche, der "Theodizee" öffentlich bezeugt haben.
Ich kann dazu nur äußern, daß es mich nicht Wunder nimmt, daß einige Wenige zu meiner Theorie in Widerspruch stehen. Weil neue Erkenntnisse stets Widerstand auslösen und die Menschen das, was sie gelernt haben, nur ungern aufgeben … Außerdem hat … Herr [Herman] Boerha[a]ve, Professor der Medizin und Botanik in Leiden, in einer öffentlichen Vorlesung die Fortpflanzungstheorien zahlreicher Autoren vorgetragen; wobei er hinzufügte, daß die meine in Deutschland, Italien, England und Frankreich allgemein gelobt werde …".

Leeuwenhoek had examined the seminal fluid of large fish, like codfish, and that of one-year-old (and slightly older) perch. The animalcula found in the semen of the smaller fish he found to be no smaller, and nonetheless livelier, than those found in the cod semen. He anticipated that the animalcula in whale semen would not be much larger than those of smaller fish; he had however tried in vain to obtain samples of whale testicles:

> "Darüber hinaus habe ich in diesem Jahr neben den vergangenen Beobachtungen nicht nur bei größeren Fischen, wie Dorschen, sondern auch bei einjährigen und etwas größeren Barschen die männlichen Samen gesehen. Im Samen der Barsche sah ich die Animalcula nicht kleiner und ebenso lebhaft schwimmen, wie im Samen der größeren Fische … Nach diesen Beobachtungen erschien mir der Gedanke nicht absurd oder unbegründet, daß im Samen des Walfisches, der im Meere schwimmen muß, die Animalcula nicht größer seien, als bei kleinen Fischen. Ich bemühte mich deshalb, Walfischhoden zu bekommen, jedoch ohne Erfolg …".

Leibniz received Leeuwenhoek's letter of 28 September 1715 on 21 October and replied accordingly on 29 October[22]. He explains that he had referred to Vallisnieri's theory not because of its credibility but rather to give the correspondent an opportunity to elaborate his views. A particular difficulty for Leibniz was to explain why twins and multiple births were so infrequent for certain animals (and for humans). Leibniz also found it remarkable that the animalcula found in the semen of large and small fish should differ inappreciably in size:

> "… Von Herr Vallisnieri einwurfen habe gedacht, nicht wegen seiner achtbarkeit, ob er schon in grosser achtung stehet, sondern weil seine einwurffe Meinem H. G. Herrn gelegenheit geben konnen allerhand gutes zu sagen … Ich bemerke eine Schwürigkeit, wie es zugehe, dass bey gewissen dieren, als Menschen zum exempel, die Zwillige so seltsam seyn, da man vermeinen solte die menge der principien könte leicht viele zugleich

[22] LBr. 538, 2; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.

herfür bringen …. Es ist merklich das die saat-thierlein des grossen und des kleinen fiches in der grösse wenig unterscheiden".

A letter from Leeuwenhoek to Leibniz dated "Delphis 18. Novembris 1715" [23]was forwarded to the physician and medical authority in Kiel Günther Christoph Schelhammer shortly before the latter's death on 11 February 1716. Once the letter had been returned, Leibniz forwarded it to yet another authority, namely Christian Wolff. In his reply from Halle on 13 May 1716 the ovist Wolff elaborates on his understanding of the theory of preformation[24]. In his view conception depended on an animalculum bestriding a cicatrice or scar of an egg. The large number of animalcula in an ejaculation was required in order to overcome the difficulty of a single individual being able to successfully bestride such a cicatrice. The animalculum did not contain the entire structure of the animal being formed but, by virtue of the organs present in the uterus, was able either to form a new embryo or to transform an existing embryo:

"In semine animalium animalcula ipsemet aliquoties non sine voluptate vidi … Hujus autem animalculi explicationem, in qua foetus formationem consistere arbitror, fieri non posse statuo, nisi in cicatriculam ovuli ingrediatur, quoniam in ovis gallinarum videmus pullum inde formari, quae tamen nonnisi a coitu foecundaunt. Cur vero tot animalculorum myriades in uno coitu cum semine immittantur, rationem hanc reddo, quia alias ob difficultatem, qua animalculum in cicatriculam ovuli cujusdam pertingere potest, vix possibilis foret conceptio. Caeterum per ea, quae paulo ante de plantis dixi, probabile mihi videtur, ipsum etiam animalculum non continere integram animalis inde formandi structuram; sed posse ope organorum, quae adsunt, in utero tum nova quaedam formari, tum ipsa praeexistentia immutari: exempla sint muli diversam utriusque sexus parentum naturam participantes."

Leibniz replied to Leeuwenhoek's letter of 18 November 1715 probably on 31 March 1716[25]. Explanation of the rarity of twins, triplets, quadruplets, etc. was now foremost in Leibniz's mind. The issue seemed to be whether it was easy or difficult for the animalcula to find landing or mooring places in the womb. If it were easy, multiple births might be the result. On the other hand, if it were excessively difficult most marriages would remain without issue or progeny which was evidently not the case. He thought it might be possible that several of the little animals might establish themselves in the womb at first but then, following a process of natural selection, only one, or just a few, would survive and develop. It was the design of the creator that predators should not become too fruitful; among such beasts of prey Leibniz included mankind, human beings. In the controversy between animalculists and ovists Leibniz saw himself close to the position of the animalculists like Leeuwenhoek and removed from that of deceased and living ovists like Johann Swammerdam (1637-1680), Theodor Kerckring (1639-1693) and Antonio Vallisnieri (1661-1730). Nicolas Andry de Boisregard (1658-1742) had, Leibniz tells the correspondent, tried in his book *De la génération des vers dans les corps de l'homme* (1700) to reconcile the contrary positions but for him this was too speculative and not rooted in observation. Leibniz's words are as follows:

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[23] *Op. Cit*. (footnote 21), *Epistola* XIX, pp. 170-182 and K. Meyer (Transl.), *Sendbrief* 19, pp. 129-136 and 234.

[24] Göttingen: Niedersächs. Staats- u. Universitätsbibliothek, cod. Ms. Philos. 138, 113-114; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.

[25] LBr. 538, 3-4; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover. Leibniz's draft of this letter is not dated but, on 28 September, Leeuwenhoek thanks him for a letter of 31 March .

"… Mich bedunkt dass noch einige Schwuhrigkeit zu finden, wegen wenigkeit der Zwillinge, Drillinge, Vierlinge, etc. bey den menschen und dergleichen thieren. Denn entweder es ist leicht oder schwehr zu vermuhten, dass das thierlein eine bequeme stelle finde. Ist es leicht, und der bequemen stellen sind viel, so solten zugleich mehr thierlein gerahten; ist es schwehr, und der stellen sind wenig, so wäre zu besorgen dass die meisten heurathen ohne erben sein wurden, da doch das gegentheil sich zeiget. Vielleicht gerahten meistentheils mehr thierlein zugleich, aber sie verhindern hernach ein ander im Wachsthum, und die natur wehlet das eine umb ihm zu helfen, und lasset die andern verderben. Es ist alles freylich von dem Urheber der Natur bestens eingerichtet, und unter andern dieses dass die Raubthiere (darunter die Menschen auch gerahten) nicht gar zu fruchtbar seyn sollen … Soviel ich spüre, scheint es Mein Hochg. Herr nicht mit dem ovario muliebri zu halten, als ob die thierlein in gewissen ovulis aufgefangen würden, da hingegen Herr Swammerdam und Herr Ker[c]kring, so vor die Eyerlein gewesen von den thierlein nichts gewust. Herr Andry [de Boisregard] in seinem Buch von Würmen, hat eines mit dem andern vereiniget, aber mehr aus bedünken, als aus observation. Herr Vallisnieri ist auch noch zur zeit vor die Ovaria, und will die Thierlein nicht zulassen. Ich erwarte seine gründe gegen die Thierlein, die mir allezeit sehr wohl gegrundet geschienen."

Leibniz's letter of 31 March 1716 crossed in the mail with Leeuwenhoek's letter of 3 (or 13) March 1716[26]. Unlike Leibniz, for Leeuwenhoek the fact of the prevalence of single births in certain species (in particular humans) in contrast to the multiple births observed in other species posed no difficulties. The bodies of women like those of cows and mares were so created that they can, as a rule, nourish only a single offspring. The large number of animalcula in mammalian or human semen was necessary because of the considerable effort required to complete the ordeal and reach their ultimate destination in the womb which was achieved by only a few. He had previously observed under the microscope how the little animals had to roll up their tails up to three times in order to advance but the breadth of a hair:

" … Ich habe früher einmal Animalcula beobachtet, die sich abmühten, den Schleim zu durchwandern, bis zu drei mal ihren Schwanz einrollen, ehe sie auch nur um Haaresbreite vorrückten…".

If finally, on arrival at their destination, three or four animalcula should penetrate an artery to find the nourishment required for growth and development, even then only the first or fittest would survive and the stragglers and weaker ones would inevitably die off. This was just like the seeds of fruit trees, where only very few develop roots when placed in the earth and, of those who do, only the strongest develop into trees. Certain types of birds like chickens, pheasants, partridges and ducks were observed to hatch out a considerable number of poults, whereas other birds like those that nest in trees produce a much smaller number of fledglings; the former follow their mothers at once seeking food for themselves, whereas those hatched out in trees remain dependent on their parents for nourishment until fully fledged. Accordingly, the latter species are able to raise only a small number of such fledglings. From this comparison Leeuwenhoek formulated a law of nature, namely that each and every animal has to nourish itself, grow up and reproduce itself according to its rule:

[26] *Op. Cit.* (footnote 21), *Epistola* XX, pp. 184-190 and K. Meyer (Transl.), *Sendbrief* 20, pp. 137-142 and 235-236; LBr. 538, 3-4; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.

"…Wir erkennen bei diesem Vergkeich ein Naturgesetz, daß nämlich ein jedes Tier nach seiner Regel ernährt, aufwachsen und sich fortpflanzen muß …".

For Leeuwenhoek it was a matter of fact that the animalcula swimming in the semen of the mammal differed little in terms of their size. In addition, he had ascertained that the eggs of both freshwater and sea fish are of the same size for young and old, for one year old and 25 year old fish, respectively. Likewise, the spawn or progeny of young (one year old) fish was not inferior in size to that of older and larger ones of the same species. Leeuwenhoek relates that he had carried out estimations of the number of eggs in the ovaries of fish; for a codfish, for example, in an ovary weighing 5 ½ pounds he had calculated a total number of 9344000 eggs:

"… Um die gleiche Zeit ließ ich das Gewicht des Ovariums einer Morua ermitteln[;] es betrug 5 ½ pondo. Dann berechnete ich sorgfältig, wieviel Kubikzoll dieses Ovarium enthielt und wieviel Eier auf einen Kubikzoll kommen, wenn sie gleichmäßig geordnet liegen. Es ergab sich, daß das Ovar 9344000 Eier enthielt …".

Only a fraction of these eggs would result in offspring and the numbers would be further reduced because some fish are devoured by others. Giant fish like dolphins and sword fish had very few offspring. All in all, he found himself flabbergasted or overawed by the numbers and the situation:

"Das sage ich: Wenn wir sorgsam und überlegt nachdenken, sind wir von alledem ratlos und können nichts tun, als vom Donner gerührt schweigen …".

The last letter from Leeuwenhoek that Leibniz received before his death is dated 19 May 1716[27]. Leeuwenhoek claims that if a woman had been so created as to allow multiple births then nature would have provided her with multiple papillae. Thus, a sow, a bitch and other female mammals that give birth to multiples, have two complete rows of nipples. The circumstance of the vast quantity of animalcula found in semen Leeuwenhoek compared to fruit trees which may live a hundred years and more and each year produce an opulence of flowers. Every flower can provide an apple or a pear for example with each fruit giving six or eight seeds, each of which in turn is capable of producing a whole new fruit tree, and so on.

Leeuwenhoek denied the existence of egg-secreting ovaries on the basis of a large number of autopsies he had carried out. Assisted by an anatomist he had undertaken post-mortem and post-coitum examinations of numerous rabbits, several bitches and also sheep. The autopsies involved careful dissection of the uteri and fallopian tubes and the removal of material in which he was able to demonstrate the presence of animalcula. He had never been able to observe a single egg which the tubes were thought to suck from the ovaries. Thus, in his role as a doubting Thomas, he writes:

" … Wenn die Verteidiger des Ovariums die Geheimnisse der Natur so sorgfältig und mit so vielen Versuchen erforschten, wie ich, so hätten sie sich noch vor mir von dem

[27] *Op. Cit.* (footnote 21), *Epistola* XXIII, p. 206-211 and K. Meyer (Transl.), *Sendbrief* 23, pp. 154-157 and 237; LBr. 538, 9-10; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.

Ovarium verabschiedet. Ich habe in diesen Jahren zahlreiche Kaninchen und mehrere Hunde decken lassen und anschliessend deren Uteri und Tuben in Anwesenheit unseres hiesigen Anatomen seziert und sodann mit der jenem eigenen Sorgfalt, das Material daraus entnommen und die darin enthaltenen animalcula den Umstehenden demonstriert. Niemals habe dabei eines jener fictiven, eingebildeten Eier gefunden, welches angeblich die Tube aus den Ovarien sauge … Diese Organe und auch Schafs-Uteri habe ich oft durchsucht … Da nun mein Wohnhaus nicht weiter als einen Steinwurf vom Hause des Metzgers entfernt liegt, konnte ich sehr viele Uteri und besonders Ovarien untersuchen. Niemals jedoch fand ich auch ein einziges jener vorgeblichen Eier, die so locker am Ovar hafteten, daß man sie mit dem Fingernagel hätte lösen können, geschweige denn, daß sie vom Ovar abgesaugt werden und dann durch die lange, enge, geknickte Tube zum Uturus zu wandern … Wie … in der Fallopischen Tube ein solcher Sog ausgeübt werden soll, das werde ich nie und nimmermehr begreifen … ".

Leeuwenhoek explained further that he had often been asked by his opponents why ovaries were present at all. His reply was that we simply don't know the function of such organs; the same argument ought to apply for the existence of breasts in men and male mammals. The mammae and the papillae were larger in woman than in men but their purpose in the latter was simply not known. By the same token, the (non-secreting) ovaries in women and female mammals should be considered the counterparts of the (seed-secreting) testicles in men:

"… Von meinen Gegenern bin ich manchmal gefragt worden, wozu denn die Ovarien überhaupt vorhanden seien. Ich muß gestehen: ich weiß es nicht. Aber wissen wir denn, warum gewisse Körperteile, die nur bei den Frauen einen bekannten Zweck haben, wenn auch kleiner auch bei Männern vorhanden sind? Die Mammae und Papillen der Frauen sind groß, die der Männer klein. Aber, frage ich, wozu sind sie denn bei den Männern überhaupt vorhanden? Die Männer besitzen Testikel; wir vergleichen sie mit den Ovarien der Frauen. Wir können also, in Umkehrung des eben gesagten sagen, daß wir deren Zweck nicht kennen. So sehen wir auch beim Ochsen kleine Papillen und auch einige andere Tiere männlichen Geschlechts besitzen solche … Kurz gesagt: Wo immer wir den Zweck einer Sache nicht erklären können, tun wir gut daran, über unsere Unkenntnis zu schweigen."

One experiment he had not carried out (and still hesitated to carry out) involved the stud service of a sheep during winter and (after an interval of two or three days) the slaughter and dissection of the animal to search for the elusive egg:

"… Man hat mir gelegentlich geraten, im Winter den Fleischer aufzusuchen, wenn er mehrere Schafe im Stall mästet. Man sollte dann einen Widder hinzustellen und zur Paarung veranlassen. Die Schafe solle ich dann ein, zwei oder drei Tage nach dem Decken schlachten lassen um nach den Ei zu suchen. Ich habe diesen Rat aber verworfen, weil es eine überflüssige sorgfältige und mühsame Arbeit bedeuten würde, ohne meine sichere Erkenntnis zu widerlegen. ...".

In a letter dated 17 November 1716 (three days after Leibniz's death in Hannover) Leeeuwenhoek included figures showing a sheep's uterus with fallopian tubes and the sheep's so-

called “egg nests” or ovaries while continuing to reject the existence of such eggs[28]. The letter in question confirms the receipt of (and replies to) Leibniz’s final letter to him (with enclosures) dated 25. September 1716. This last letter from Leibniz to Leeuwenhoek contains two attachments. Leibniz had forwarded Leeuwenhoek’s letter of 19 May 1716 though an intermediary, namely Michael Gottlieb Hansch, to Johann Wilhelm Pauli (1658-1723) und Martin Naboth (1675-1721), two medical authorities in Leipzig and proponents of the ovist interpretation in the theory of preformation. Each of them had supplied a comment or expert's opinion on Leeuwenhoek’s letter and communicated these through Hansch to Leibniz who duly attached them to his letter of 25 September to Leeuwenhoek. Pauli remarks that others had observed post-coital changes to the ovaries and he had difficulty in accepting Leeuwenhoek’s view that only one, or just a few, from many thousand animalcula could establish itself in the womb[29]:

> “Leuvenhoeck handelt allein in seinem letzten Schreiben vom 19. May hujus anni von den Ovariis et Tuba Fallopiana animalium, und negiret deßwegen die ovula, weil er solche niemahls in Caninchen, noch Hunden oder Schaffen finden können. Nachdem aber von anderen in den Ovariis post coitum eine große alteration gefunden, auch die tuba extremitui ad ovarium angemerket worden, ist wohl solchen mehr Glauben beyzumeßen, zumahl es sapientiae divinae zu repugnieren scheinet, daß unter so viel 1000 vermiculis, welche nach seiner Meinung in semine masculino sich befinden sollen, nur ein eintziger oder sehr wenige zur Reiffe und Wachsthum gelangen: Er auch auff die frage, worzu ein solcher numerus diene, nicht so wohl directe, als indirecte geantwortet.”

Naboth, for his part, had described in his dissertation *De Sterilitate Mulierum* (published 1709 in Leipzig) retention cysts that develop in the portio vaginalis cervicis, that is the portion of the uterine cervix that projects into the vagina in women. These cysts had first been described by the French surgeon Guillaume Desnoues in a publication of 1681. They later came to be known as “Ovula Nabothi” having been so designated by Albrecht von Haller (1708-1777) and they were erroneously treated as the true ovula or eggs[30]. In his dissertation about the infertility of women Naboth had postulated the cystic portio as the “egg nest” or “ovarium genuinum”. Naboth’s statement about Leeuwenhoek’s letter to Leibniz of 19 Mai 1716 contains the opinion and conviction that this “ovarium genuinum” is to be found in the cavity of the uterus (i.e. the cervix or cervical canal) in humans and in the fallopian tubes in most mammals. The text is as follows[31]:

> “Weil die bewegung und gestalt derer Vermeineten vermiculorum, in semine humano, canino etc. Sexus masculini nicht allezeit einerley verspuret wird, auch eben dergleichen bewegung und gestalt in andern warmen Liquoribus zu sehen, ist also nicht viel von dieser Meinung zu halten. Vielmehr findet man das ovarium genuinum, in corpore humano, in cavitate uteri, in denen meisten brutis in den tubis Fallop. mit ihren Placentis[,] funiculo umbilicali, tunicis et liquore, nebst der gantzen delineation totius corporis, ante congressum und hat H. Lewenhoeck in diesem Stucke recht daß Er das ovarium ad latera

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[28] *Op. Cit.* (footnote 21), *Epistola* XXX, p. 287-300 (see Fig. 1, 2 & 3 p. 300) and K. Meyer (Transl.), *Sendbrief* 30, pp. 218-219 and 237.
[29] LBr. 538, 7; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.
[30] On the history of the nabothian cyst see: Thiery, Michel: “Martin Naboth (1675-1721) en de Ovula Nabothi”, in: *Tijdschrift voor Geneeskunde*, vol. 61, no. 13 (2004), pp. 1015-1016.
[31] LBr. 538, 8; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.

uteri exterius situatum, verworfen, hingegen das von Ihm substituirete ist nicht zu demonstriren."

Leibniz explains in his final letter to Leeuwenhoek of 25 September 1716 that he had forwarded Leeuwenhoek's letter of 19 May 1716 to the anatomists Pauli and Naboth in Leipzig. Both were adherents of the ovist (and antagonists of the animalculist) interpretation whereas he himself held the latter position to be credible. The key issue remained the position and the function of the ovaries. Leeuwenhoek's réplique to the objections of the anatomists of Leipzig would, he tells the correspondent, have most weight in the discussion of the important issue of the nature and mechanism of sexual reproduction. Leibniz's final words to Leeuwenhoek are as follows[32]:

"Weil ich wündsche daß die guhte Kundschafft und briefwechslung mit demselben zu gemeinen nuzen gereichen möge. so habe deßen leztes darinn vom Eyerstock der thiere gehandelt nach Leipzig geschickt, und daselbst guhten Anatomicis, H. D. Pauli Professoren des ohrts und H. D. Naboth communiciren laßen. Die loben M. h. H. meynung, darum daß er solchen eyerstock an dem insgemein angegebenen ohrt verwirfft. Vermeynen aber selbigen anderswo zu zeigen, darüber ich M. h. H. urtheil erwarte. Beide sind gegen die saamenthiere, die mir doch glaubwürdig vorkommen. Ich habe auff ihre Einwurffe in lateinischer Sprache wie M. h. H. aus der beylage sehen wird, vorgangig zwar geantwortet[,] aber Meines Hochg. H. eigne antwort darauff wird das beste gewicht haben, und dienen dieses wichtige werck beßer zu beleüchten."

Leibniz's commentary in Latin on the statements of Pauli and Naboth[33], referred to here, indicates that his final service to science, technology and medicine was probably in the field of gynecology and represented his final endorsement of the animalculist interpretation in the theory of preformation as opposed to the ovulist interpretation and belief in the existence of (but not yet observed) mammalian and human eggs. According to the animalculists, fish and fowl developed from eggs but not mammals and humans.

The fact that mammals and humans do develop from eggs was first established by Karl Ernst von Baer in 1827, more than a hundred years after the deaths of Leibniz and Leeuwenhoek in 1716 and 1723, respectively.

[32] Göttingen: Niedersächs. Staats- u. Universitätsbibliothek, cod. Ms. Philos. 138, 52; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.

[33] The item in question remains to be identified. See, however Leibniz's letter to Michael Gottlieb Hansch of September 25, 1716: Göttingen: Niedersächs. Staats- u. Universitätsbibliothek, cod. Ms. Philos. 138, 33; Online transcription provided by Leibniz-Archiv / Leibniz-Forschungsstelle, Hannover.