Notes on the Early History of Microscopy

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NOTES ON THE EARLY HISTORY OF MICROSCOPY.

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In view of the immense interest in microscopic investigation evinced during the last fifty years, it is remarkable that no exhaustive history of the instrument has yet appeared. Many points in the earlier history of the subject remain doubtful, and in spite of the helpful essays of P. Harting[1] in Holland, of Landsberg[2] and Petri[3] in Germany, and of Vincenzo Rocchi[4] in Italy, there are still gaps in existing accounts. English literature on the subject is particularly scanty.[5] We have, therefore, endeavoured in the following pages to place before the reader a short and consecutive account, giving especial attention to the recorded observations of some of the earliest workers.

(I) The Simple Microscope.

The use of lenses may be certainly traced back to the thirteenth century, and is not improbably of far earlier origin. It seems likely that spheres of glass filled with water were used as magnifiers by the gem cutters of antiquity, whose work could hardly have been accomplished without some aid to vision. Pliny[6] mentions that burning-glasses were used by physicians as cauteries. "Letters, however small and dim," says Seneca[7] (*c.* A.D. 63), "are comparatively large and distinct when seen through a glass globe filled with water." The Indian drama "Sākuntalā"[8] of Kālidasā also distinctly refers to burning-glasses.

[1] P. Harting, "Het Mikroskoop, deszelfs gebruik, geschiedenis en tegenwoordige toestand," 3 vols., Utrecht, 1848-50.

[2] C. Landsberg, *Central Zeitung f. Optik u. Mekanik*, 1890, p. 272 (unfinished).

[3] B. J. Petri, "Das Mikroskop," Berl., 1896. Historical introduction.

[4] Vincenzo Rocchi, "Appunti di Storia Critica del Microscopio," *Rivista di Storia Critica delle Scienze Mediche e Naturali*, January, 1913, anno iv, p. 1.

[5] There are, however, the Cantor Lectures of John Mayall, published in the *Journal of the Society of Arts* for 1886. Professor L. C. Miall has also dealt with much learning on the classical microscopists in his work on "The Early Naturalists," Lond., 1912.

[6] C. Plinius Secundus, "Naturalis Historia," xxxvi, p. 67 and elsewhere.

[7] Lucius Annaeus Seneca, "Quaestiones Naturales," book i, ch. vi.

[8] Kālidasā, "Sākuntalā," act ii. Orientalists usually date this work between A.D. 300 and A.D. 600.

The general principles of reflection with some idea of the refraction of light, and notably the optical properties of curved mirrors, were comprehended by Euclid (or at least by a writer using his name) in the third century B.C. as well as by the mathematician Ptolemy, in the second century A.D. The knowledge of these writers was handed on to mediæval Europe by the Arab, Alhazen (died 1038), who developed the ideas of his predecessors as applied to curved mirrors in considerable detail and with great mathematical skill. Alhazen was aware of the action of reflecting surfaces, formed by the rotation of a conic section, and he was, therefore, able accurately to project magnified images.[1] His work was familiar to at least two thirteenth century writers on optics, Vitello or Witelo, who attempted to use segments of glass balls to get a better view of small objects, and Roger Bacon, who had a clear conception of the simple microscope and of the possibility of bringing distant objects near and of indefinitely magnifying minute objects, by giving suitable direction to refracted rays and by the use of appropriate media.[2]

In Europe the invention of convex glasses for use as spectacles is attributed to Salvino d'Amarto degli Armati, of Florence, and to Alessandro de Spina, of Pisa, about the year 1300.[3] The first mention of these instruments is, however, said to be by Bernard de Gordon (died *c.* 1307) in his "Lilium Medicinæ."[4] It is remarkable, although fully in accord with what we know of the absence of

[1] The earliest printed edition of Alhazen's "Thesaurus Opticae" is the Latin translation, probably by Gerard of Cremona, of 1542. Another edition, combined with the "Optics" of Vitello, appeared in 1572. For an analysis of the mathematical knowledge of Alhazen, see Moritz Cantor, "Vorlesungen über Geschichte der Mathematik," Leipz., 1880, i, p. 677.

[2] For Roger Bacon's knowledge of optics see "The 'Opus Majus' of Roger Bacon, with Introduction," by J. H. Bridges, Oxf., 1897, p. lxix *ff.*, and parts iv and v of the "Opus Majus" itself. Also E. Wiedemann and S. Vogl in "Roger Bacon, Essays . . . . collected and edited by A. G. Little," Oxford, 1914.

[3] *See* Hörner, "Ueber Brillen aus alter und neuer Zeit," 1885; P. Pansier, "Histoire des Lunettes," Par., 1901; E. Bock, "Die Brille und Ihre Geschichte," Vienna, 1903; Du Bois-Raymond, "Zur Geschichte der Glass Linsen," 1905; Hirschberg, in "Geschichte der Augenheilkunde," Leipz., 1906, Buch ii, Teil 2; B. Laufer, in "Mitteilungen zur Geschichte der Medizin und Naturwissenschaften, 1907, vi, p. 379; E. H. Oppenheimer, "Die Erfindung der Brille," in *Zentralzeit. f. Optik u. Mechanik*, 1908, p. 13; R. Greeff, "Die ältesten uns erhaltenen Brillen," in *Arch. f. Ophthal.*, Wiesb., 1912, lxxii, pp. 44-51. The rôle of Salvino d'Amarto and Alessandro de Spina has been recently rediscussed by Vincenzo Rocchi, "Appunti di Storia Critica del Microscopio," in the *Rivista di Storia Critica delle Scienze Mediche e Naturali*, January, 1913, anno iv, No. 1, p. 4 *ff.*, and by G. H. Oliver, in the *Brit. Med. Journ.*, 1913. It is alleged that, among the Chinese, spectacles were already being used in the thirteenth century. See, however, Hirschberg in "Mitteilungen zur Geschichte der Medizin," 1907, vi, p. 550.

[4] Written about 1300. First printed, Venice, 1496.

mediæval interest in "phenomena," that such magnifying lenses do not seem to have been used for the investigation of Nature.

In the sixteenth century, however, curiosity in scientific matters began to assert itself. That universal genius, Leonardo da Vinci (1452-1519), had already investigated some of the effects of concave, as well as of convex, glasses,[1] while those interested in alchemy frequently used flasks filled with water, concave mirrors or else glass balls to concentrate rays of the sun.[2] Moreover, some of the optical properties of lenses were enunciated by Maurolico[3] (1494-1575), and later by

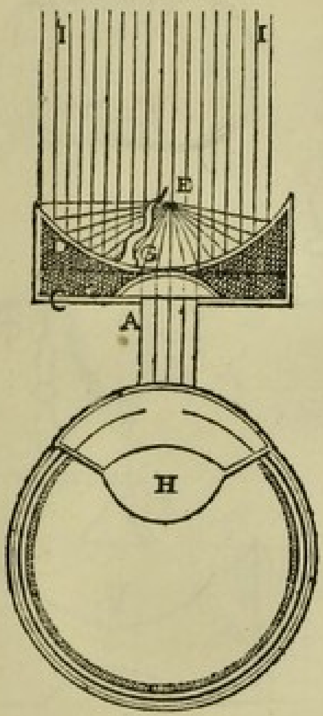


FIG. 1.

Descartes' diagram of a simple microscope from his "Dioptrique" of 1637.

Kepler[4] (1571-1630). Long before the dawn of the seventeenth century the principle of the lens was both comprehended and applied to scientific matters by the Englishmen, Leonard Digges and his son Thomas, and by the Italian, Giambattista Porta.

[1] *See* Otto Werner, "Zur Physik Leonardo da Vincis," Berl., 1911, p. 142.

[2] *See*, e.g., Conrad Gesner's "Thesaurus Euonymi Philiatri de Remediis secretis," Zurich, 1554, p. 100.

[3] Francesco Maurolico, "Photismi de lumine et umbra ad perspectivam radiorum incidentium facientes," Venice, 1575.

[4] Johannes Kepler, "Astronomiae Pars Optica," 1604, and "Dioptrice," Augsburg, 1611.

Interest in the minute structure of natural objects appears to have especially developed towards the end of the sixteenth and during the first third of the seventeenth century. Thus, it is likely that the naturalist Thomas Mouffet had used magnifying glasses for his researches on scabies as early as the year 1590,[1] and in 1637 Descartes described in his "Dioptrique" a somewhat elaborated form of the unilenticular microscope, with which rays of light are focused on the

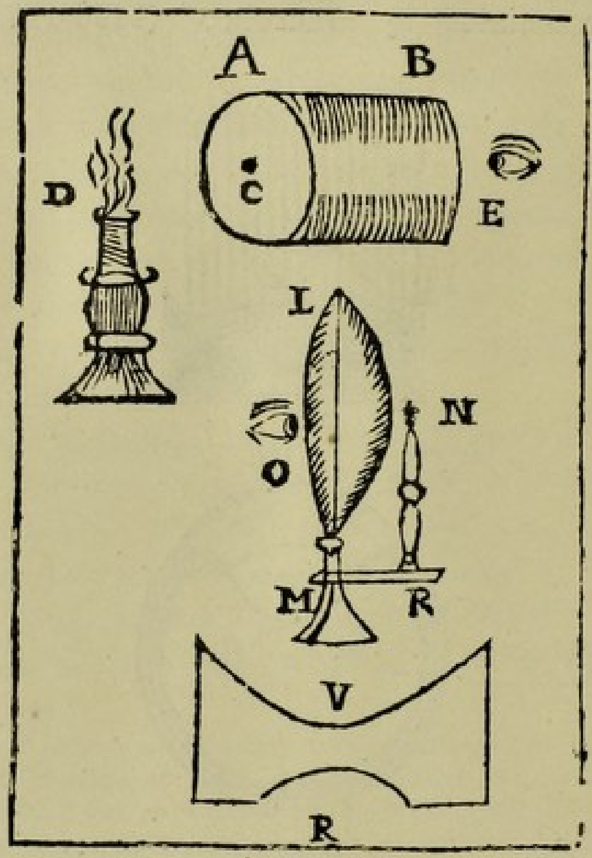


FIG. 2.

Kircher's diagram of a simple microscope (upper figure) from his "Ars Magna Lucis" of 1646, p. 835. The insect to be examined is placed on the glass plate at C and illuminated by the candle D, the lens being at the opposite end, E, of the tube A B.

object by means of a concave mirror. There is a central transparent area in the mirror behind which the lens is placed (fig. 1).

With the process of development of the compound microscope we shall deal in the next section. It is here sufficient to say that the simple microscope was a natural development of the lens, but that

[1] See his "Insectorum sive minimorum animalium theatrum," Lond., 1634. Posthumously edited by T. T. de Mayerne.

even early microscopic pioneers, such as Fontana and Borel, availed themselves of the increased magnifying power produced by the compound system. With the improvement in the grinding of glasses, however, workers avoided the chromatic aberration and extremely small field of the compound instrument by reverting to the single lens. It was, indeed, mainly with such simple microscopes that the early historic microscopic discoveries were achieved.

The earliest microscopes consisted of a short tube of opaque material, with a lens at one end, and at the other a flat glass plate on which the

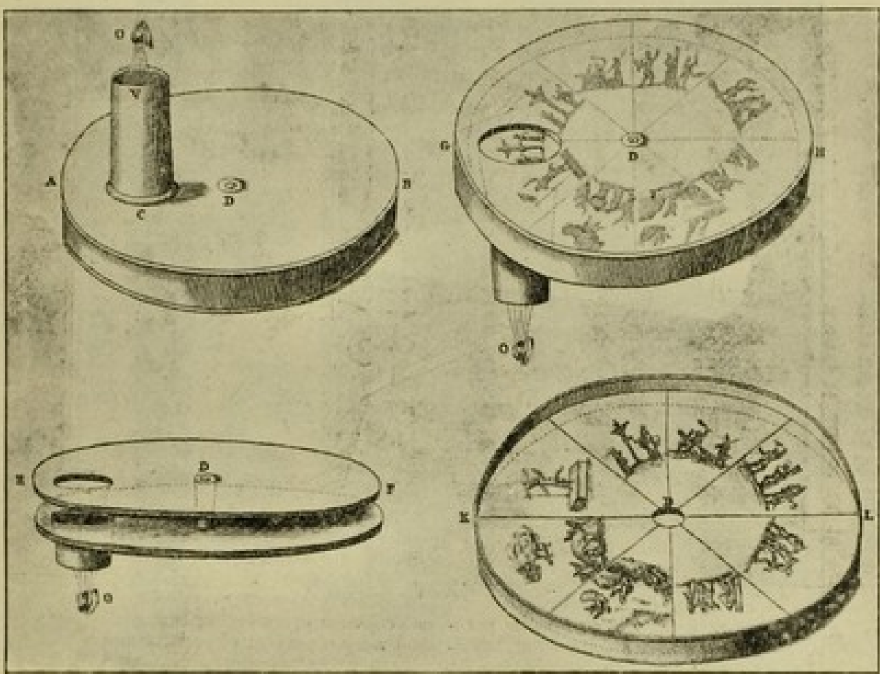


FIG. 3.

Kircher's "Smicroscopium parastaticum."

object to be examined was placed. Such simple instruments were sometimes spoken of as "Vitrea pulicaria," or "Vitrea muscaria," from their use in the examination of small insects. Subsequently they came to be known as "Engyoscopes," and are spoken of as childish instruments, "Microscopia ludicra," as opposed to the compound "Microscopia seria."[1] We give a figure of an instrument of this type as at first used by Athanasius Kircher (fig. 2). By 1663 well-made instruments of this form were in common use in Holland. Thus at

[1] Johannes Zahn, "Oculus Artificialis," Herbipoli, 1685, iii, p. 109.

Leyden in that year Isaac Voss, of Hamburg, showed Monconys his microscope, " which is but a minute hemispherical lens, fixed in a small piece of wood, which is let into a little black table. The hollow for the eye is pierced by a very small hole."[1] A slight advance on this form was later adopted by Kircher. He had a series of objects mounted

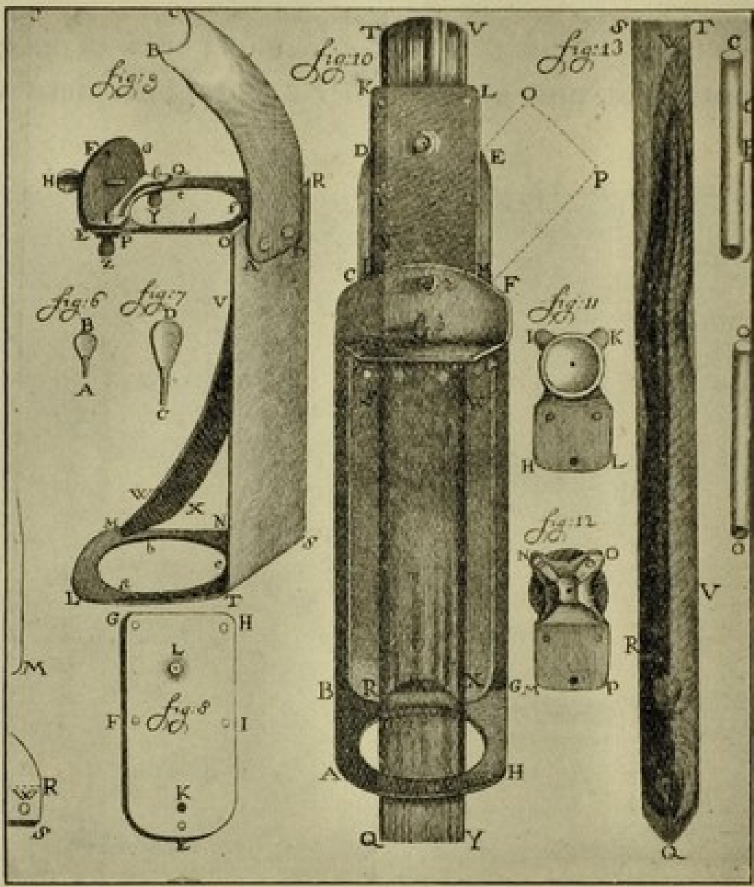


FIG. 4.

One of Leeuwenhoeck's microscopes. It consists merely of a metal plate (shown in detail in fig. 8) pierced by a small hole into which a minute lens (L) is fitted. This plate fits on a frame (shown in detail in fig. 9) into which a tube (fig. 13) containing a small live eel is placed. By adjusting screws the tail of the eel can be brought into focus, and the capillary circulation examined. The apparatus is shown fitted up in fig. 10.

upon a rotating disc, which thus brought one after the other in front of the eye. This instrument he speaks of as the " Smicroscopium parastaticum " (fig. 3).[2] But the great improvement made with instruments

[1] Monconys, "Journal des Voyages," Par., 1677, part ii, pp. 153, 161.

[2] The figure we reproduce is from the edition of the "Ars Magna Lucis et Umbrae," Amsterdam, 1671, part iii, 9, p. 770. The instrument is described, but not figured on p. 837 of the Rome (1646) edition.

of this type was the introduction of lenses of very short focal length. As early as 1665, Robert Hooke used for the purpose small glass balls formed by fusing threads of drawn glass.[1] Later, Hooke greatly improved on these. Excellent spherical lenses were also made by Hartsoeker, who was using them about 1668. Butterfield[2] and Jan van Mussenbroeck were a little later in the field.

It was Antony van Leeuwenhoeck, however, who perfected these instruments. He brought an extraordinary skill and industry to bear on the grinding and polishing of minute lenses of short focal length. Already in 1673 Regnier de Graaf wrote to the Royal Society in London that Leeuwenhoeck was making glasses far superior to those of the

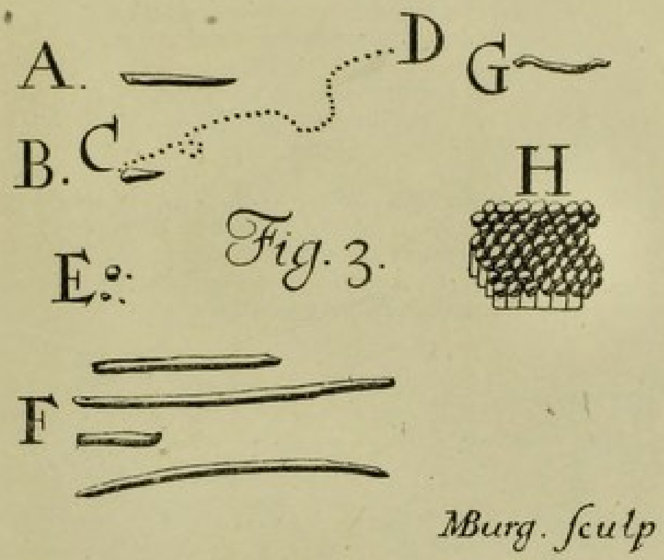


FIG. 5.

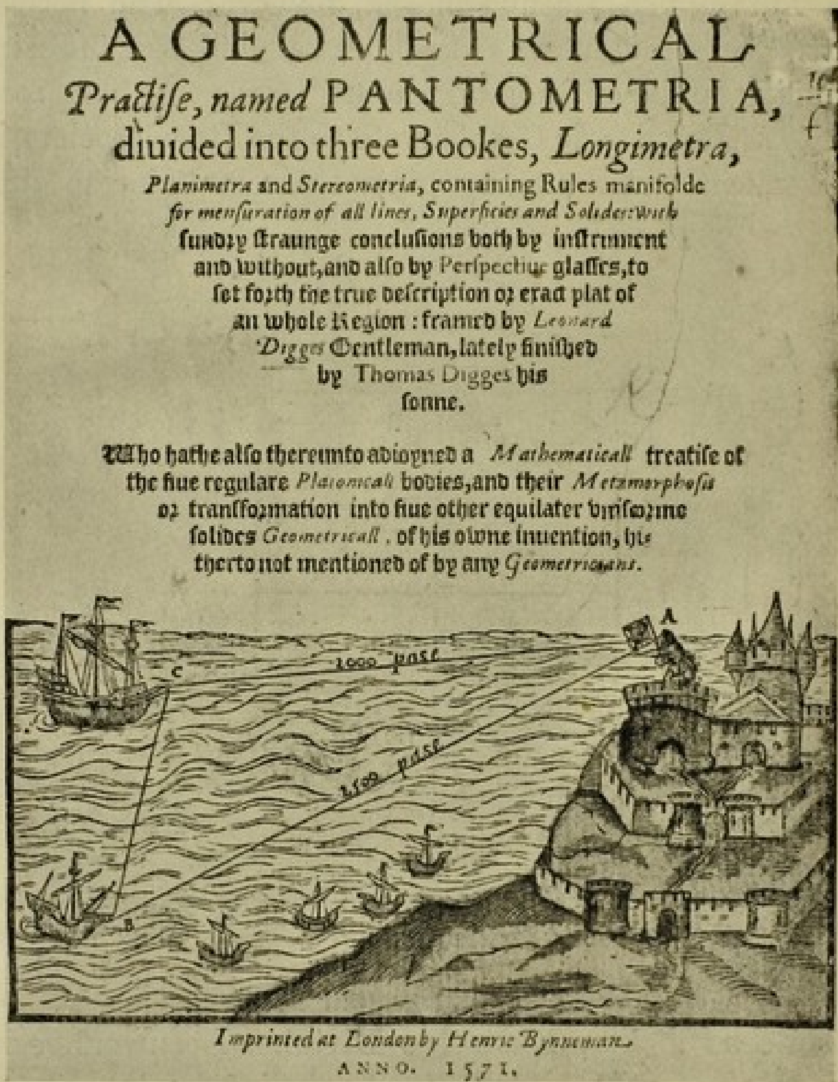
Bacteria as figured by Leeuwenhoeck (*Phil. Trans.*, 1683). At E, cocci are shown; at A, F, and G, rod-shaped organisms; at H, sarcinæ; and at C a flagellated organism.

great Italian lens maker, Eustachio Divini. Leeuwenhoeck's success was largely due not only to his method of grinding, but also to the skill with which he mounted his lenses, which were accurately fitted into a minute hole in a metal plate. The object to be examined was firmly held in a stand and adjusted by means of a screw movement to the plate (see description of fig. 4). By this means, and by the use of hollow metal reflectors, he succeeded in availing himself of transmitted light in the case of transparent objects. Leeuwenhoeck was able to

[1] Mentioned in *Phil. Trans.*, March 4, 1678, and in "Micrographia," Lond., 1665.

[2] *Phil. Trans.*, 1677, p. 226.

make immense advances with these instruments; rotifera and infusoria he could see with ease, and by 1683 he had even attained a sight of the bacteria (fig. 5). Instruments similar to these of Leeuwenhoeck seem to have been used by Malpighi, who, however, also employed the compound apparatus.



A GEOMETRICAL
Practise, named PANTOMETRIA,
diuided into three Bookes, *Longimetra,*
Planimetra and *Stereometria*, containing Rules manifolde
for mensuration of all lines, Superficies and Solides: with
sundry straunge conclusions both by instrument
and without, and also by Perspectiue glasses, to
set forth the true description or exact plat of
an whole Region: framed by *Leonard*
Digges Gentleman, lately finished
by Thomas Digges his
sonne.

Who hathe also thereunto adioyned a *Mathematicall* treatise of
the fiue regulare *Platonicall* bodies, and their *Metamorphosis*
or transformation into fiue other equilater uniforme
solides *Geometricall*, of his owne inuention, hi-
therto not mentioned of by any *Geometricians*.

Imprinted at London by Henrie Bynneman.
ANNO. 1571.

FIG. 6.

Title-page of Digges's "Pantometria," 1571.

Leeuwenhoeck's researches represent the high-water mark of work done with the simple microscope. Considerable advances were made on his instruments in the following century, but their application was to a different class of object, and they are outside our present scope. After Leeuwenhoeck, most high-class microscopic work was accomplished with the compound instrument.

(II) The Compound Microscope.

The earliest history of the compound microscope is inextricably involved with that of the telescope, and must in the first instance be considered with it. Setting aside certain unverifiable claims, probably the first writer who suggested the possibility of using a system of lenses for the purpose of making a distant object apparently nearer was the

Fig. 7.

Giambattista della Porta.

English mathematician, Leonard Digges (died 1571). In a work published by his son shortly after the father's death (fig. 6) we read that "marueylouse are the conclusions that may be perfourmed by glasses concaue and conuex of circulare and parabolicall fourmes, using for multiplication of beames sometime the ayde of glasses transparent, which by fraction should unite or dissipate the images or figures presented by the reflection of other. By these kinds of glasses or rather frames of them, placed in due angles, ye may not only set out the proportion of an whole region, you represent before your eye the lively image of euery towne, village, etc., and that in as little or great space or place as ye will prescribe, but also augment and dilate any parcell thereof, so that whereas at the firste apparance an whole towne shall present it selfe so small and compacte together that ye shall not discerne any difference of streates, ye may by applycation of glasses in due proportion cause any peculiare house or roume thereof dilate, and shew it selfe in as ample fourme as the whole towne first appeared, so that ye shall discerne any trifle or reade any letter lying there open, especially if the sonne beames may come unto it, as playnly as if you wer corporally present, although it be distante from you as farre as eye can discrye. But of these conclusions I minde not here more to intreate, hauing at large in a volume by it selfe opened the miraculous effectes of perspective glasses."[1] Digges's system appears to have been combined in some manner with a camera obscura. Unfortunately, his further description of it was never published.

The idea, however, was taken up by Porta (fig. 7), a writer who, although not himself original, was gifted with great curiosity and industry in the collection of the ideas of others. In the 1588 edition of Porta's "Magia Naturalis," a hotchpotch of the wonders that were then exciting the interest of mankind, we read how "to make plain a letter held far away by means of a lens of crystal." He was apparently himself myopic, for he says that "concave lenses enable one to see far off more clearly while convex ones make near objects more discernible," and he goes on to say that "with a concave lens you see things afar smaller but plainer, with a convex lens you see them larger but less distinct. *If, however, you know how to combine the two sorts properly* you will see near and far both large and clear."[2]

At some date shortly after the publication of Porta's work a practical application of the combination of two lenses into a microscope or telescope was made by the Dutchman Zacharias, miscalled Jansen[3] (fig. 8).

[1] "A Geometrical Practise named Pantometria . . . framed by Leonard Digges Gentleman, lately finished by Thomas Digges his sonne," Lond., 1571. Suggestions as to the nature of Digges's apparatus are made by Major-General J. Waterhouse, "Proceedings of the Optical Convention," 1905, p. 115.

[2] G. Battista della Porta "Magia Naturalis," Naples, 1588, lib. xx. There are earlier editions from 1558 onwards, which, however, do not include this passage. These earlier editions, nevertheless, show a full knowledge of the properties of convex lenses as burning glasses and magnifiers.

[3] The name Jansen is due to a misunderstanding. Zacharias was indeed the son of John, the spectacle maker, but *Jansen* was not, in this case, a surname. *See* Vincenzo Rocchi, loc. cit., p. 9.

Zacharias was born at Middelburg in Holland about 1580, and about 1590, while still a lad and at work in the shop of his father who was a spectacle maker, he appears to have discovered accidentally the principle of the telescope, by placing two lenses together in a tube.[1]

ZACHARIAS IANSEN

FIG. 8.

From Borel's "De Vero Telescopio Inventore."

The invention of the microscope followed at some unknown date. The event is thus described by Willem Boreel (1591-1668), the Dutch ambassador to France,[2] in a letter to the Frenchman, Pierre Borel:

[1] The scanty details of the life of Zacharias are given in A. J. van der Aa's "Biographisch Woodenboek der Nederlander Negende," Haarlem, 1860.

[2] *See* Pierre Borel, "De vero telescopii inventore cum brevi omnium conspiciliorum historia," The Hague, 1655, p. 34 *ff*.

"I am a native," says Boreel, "of Middelburg, the capital of Zeeland, and close to the house where I was born . . . there lived in the year 1591 a certain spectacle maker, Hans by name. His wife, Maria, had a son Zacharias whom I knew very well, because I constantly as a neighbour and from a tender age went in and out playing with him. This Hans or Johannes with his son Zacharias, as I have often heard, were the first to invent microscopes, which they presented to Prince Maurice, the governor and supreme commander of the united Dutch forces, and were rewarded with some honorarium. Similarly they after-

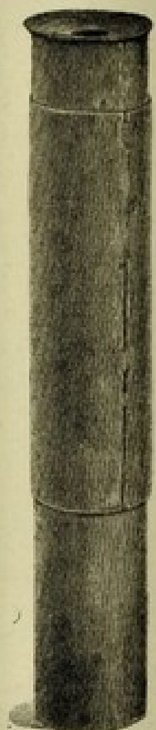


Fig. 9.

Instrument discovered by Harting at Middelburg in 1866, and assigned to the earlier part of the seventeenth century. It is perhaps the oldest compound microscope now in existence and has been erroneously attributed to Zacharias. (Reproduction by kind permission of Sir Frank Crisp.)

wards offered a microscope to the Austrian Archduke Albert, supreme governor of Holland. When I was ambassador to England in the year 1619, the Dutchman Cornelius Drebbel of Alkomar, a man familiar with many secrets of nature; who was serving there as mathematician to King James, and was well known to me, showed me that very instrument which the Archduke had presented as a gift to Drebbel, namely, the microscope of Zacharias himself. Nor was it (as they are now seen) with a short tube, but nearly two and a half feet long, and the tube was of gilded brass two fingers' breadth in diameter, and supported on three dolphins formed also of brass. At its base was an ebony disc, containing shreds or some minute objects which we inspected from above, and their forms were so magnified as to seem almost miraculous." [1]

This report is supported in almost every detail by evidence collected by Pierre Borel from the town councillors of Middelburg. The microscope is no longer in existence, but we are able to show pictures of

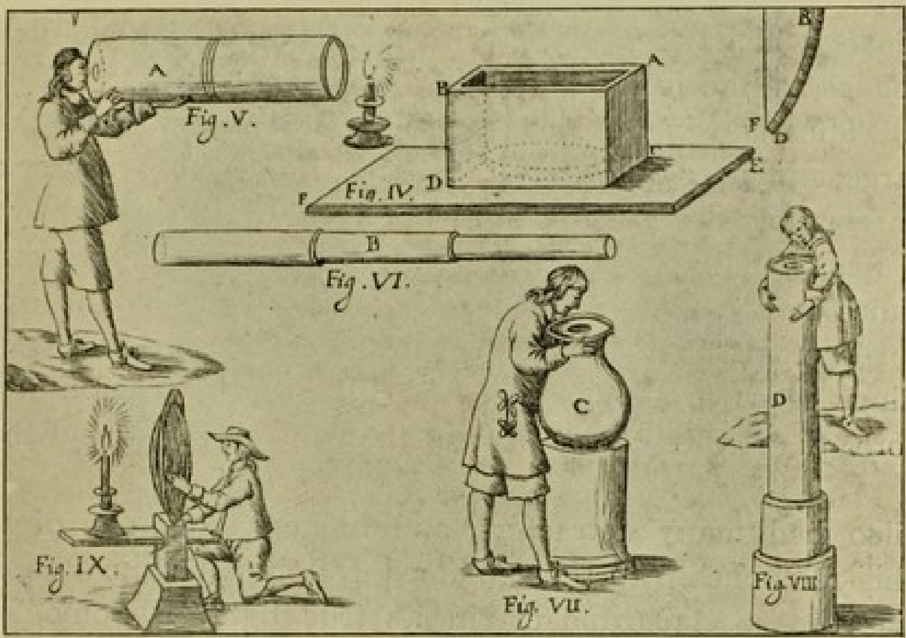


FIG 10.

Microscopes from C. Schott's "Magia universalis," 1656.

instruments no less vast and clumsy which were in use as late as 1656 by C. Schott [2] (fig. 10).

There seems no reason to doubt the very circumstantial account given by William Boreel, and the honour of having constructed the first bilenticular instrument, albeit perhaps accidentally, rests with Zacharias, who was closely followed by another Dutch lens maker,

[1] P. Borel, "De vero inventore," p. 29 *ff.*

[2] C. Schott, "Magia universalis," 1656. In the opinion of Sir Frank Crisp, however, the apparent size of these microscopes was due to an error of the engraver, who placed an entire figure where the draughtsman had only placed an eye.

Joannes Laprei or Lipperhey, of Wesel. The real work, however, of introducing it to the notice of the scientific world lay with Galileo, whose own account of the matter we now give from the "Sidereus Nuncius," published at Venice in 1610: "About ten months ago," he says, "a rumour reached me of an ocular instrument made by a certain Dutchman by means of which an object could be made to appear distinct and near to an eye that looked through it, although it was really far away. . . . And so I considered the desirability of investigating the method, and I reflected on the means by which I might come to the invention of a similar instrument. A little later, making use of the doctrine of refractions, I first prepared a leaden tube at the ends of which were placed two lenses each of them flat on one side, and as to the other side I fashioned one concave and the other convex. Then moving the eye to the concave one, I saw the objects fairly large and nearer, for they appeared three times nearer and nine times larger than when they were observed by the naked eye. Soon after I made another more exactly, representing objects more than sixty times larger. At length, sparing no labour and no expense, I got to the point that I could construct an excellent instrument so that things seen through it appeared almost a thousand times greater and more than thirty-fold nearer than if observed by the naked eye."

Galileo had many detractors, and in answering one of them he places his relationship to the unnamed Dutchman (who was doubtless Zacharias the spectacle maker) in its true light. "Some," he says, "would tell me that it is of no little help in the discovery and resolution of a problem to be first of all in some way aware of the true conclusion and certain of not being in search of the impossible, and that therefore the knowledge and the certainty that the microscope had indeed been invented had been of such help to me that perchance without that I should not have discovered it. To this I reply that the help rendered me by the knowledge did indeed stimulate me to apply myself to the notion, and it may be that without this I should never have thought of it. Beyond this I do not believe that knowledge to have facilitated the invention. But after all the solution of a problem, thought out and defined, is a work of some skill and we are not certain that the Dutchman, the first inventor of the telescope, was not a simple maker of ordinary lenses who, casually arranging glasses of various sorts, happened to look through the combination of a convex and a concave one placed at various distances from the eye and in this way observed the effect that followed thereon. But I, moved by the knowledge given, discovered it by a process of reasoning."[1]

Galileo's "Sidereus Nuncius" contains also the first rough figure of the path of the rays of light in a bilenticular system, the theory of

FIG. 11.

Francisco Fontana, the astronomer, from his "Novae Cœlestium Terrestriumque Observationes," 1646.

which was more clearly expressed by Johannes Kepler in the year 1611.[2] Although, however, so large and important a share in the invention of the compound microscope and telescope rests with Galileo

[1] Galileo Galilei, "Il Saggiatore nel quale conbilancia esquisita e guista si ponderano le cose contenute nella Libra astronomica e filosofica di Lotaris Sarsi Sigensans," Rome, 1623, p. 62.

[2] J. Kepler, "Dioptrice, seu Demonstratio eorum quae visui et visibilibus propter conspicilla non ita pridem inventa accidunt. Praemissa Epistolae Galilaei de iis quae post editionem Nuncii siderii ope Perspicilli, nova et admiranda in coelo deprehensa sunt. Cologne 1511." See especially problemata 86 and 87.

and Kepler, yet the theory of the instrument, even apart from chromatic aberration, could not have been on a satisfactory basis until the work of Wilibrod Snell van Royen (1581-1626) on the reflection and refraction of light, and his enunciation of the "sine law" about 1620.

Perhaps one of the earliest practical users of the compound microscope was the astronomer Francisco Fontana, of Naples (fig. 11). In 1646 was first published his "New Observations of the Things of Heaven

FIG. 12.

Title-page of Fontana's work containing microscopical observations, 1646.

and of Earth"[1] (fig. 12). This work is chiefly valued for an admirable illustrated account of the transit of Venus, as well as of Saturn's rings, Jupiter's belts and the surface of the moon as investigated by means of his telescope. The book is divided into eight tractates, of which the first seven are astronomical. The eighth tractate is entitled

[1] "Novae Caelestium terrestriumque rerum observationes et fortasse hactenus non vulgatae a Francisco Fontana specillis a se inventis et ad summam perfectionem productis editae," Naples, 1646.

"Of the Microscope, by means of which the most minute and quasi-invisible things are so enlarged that they may be clearly and distinctly seen." He here claims to have invented the compound instrument as early as 1618, and produces evidence that he was already using it in 1625.

That the microscope was fairly well known in Italy about this time may be gathered from a passage in a most curious and beautifully illustrated work on the then newly discovered sun spots, produced

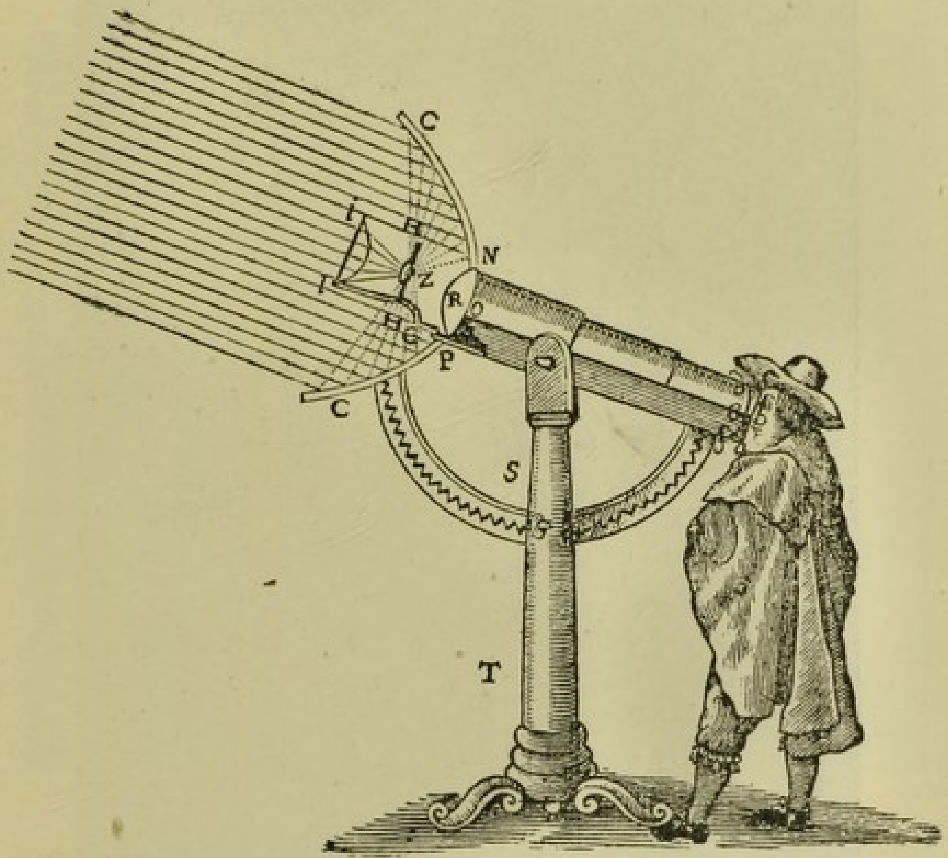


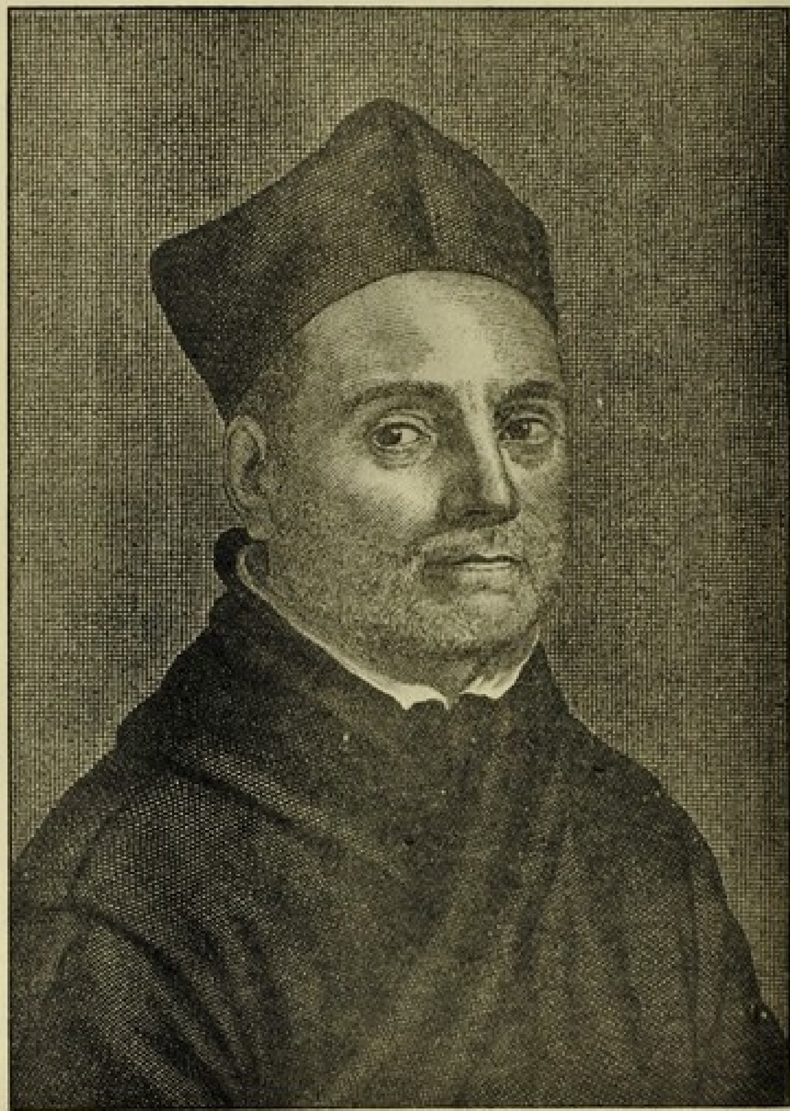
FIG. 13.

Descartes's microscope. From his "Dioptrique," 1637.

by Christopher Scheiner between 1626 and 1630 and entitled "Rosa Ursina."[1] Scheiner describes how "if two convex smoked lenses are fixed correctly in a tube, they make an admirable helioscope," and goes on to say that "in the same fashion is constructed that wonderful

[1] Christopher Scheiner, "Rosa Ursina sive sol ex admirando facularum et macularum suarum Phaenomeno varius. Bracciani Impresso coepta Anno 1626 finita vero 1630, Id. Junii." Quotation from lib. ii, cap. xxx, p. 130, I. 33.

instrument the microscope, by means of which a fly is magnified into an elephant, and a flea into a camel, and other things are rendered apparent which escape the acuteness of the human eye by reason of their extreme smallness."



P. ATHANASIVS KIRCHERVS FVLDENSIS
ê Societ: Iesu Anno ætatis LIII.
Honoris et observantiæ ergo sculpsit et D.D.C. Bloemaert Romæ 2 Maij A. 1655

FIG. 14.

A curious and aberrant form of compound microscope was described in 1637 by the philosopher Descartes, in his "Dioptrique."[1] This

[1] "René Descartes, La Dioptrique," ninth discourse. The "Dioptrique" was published as an appendix to the "Discours de la Méthode," Leyden, 1637.

instrument, which was really an adapted telescope, consisted of an adjustable tube carrying two lenses (fig. 13). The ocular was plano-concave, while the double convex objective was mounted in the centre of a concave mirror adapted to concentrate parallel rays on to the object. Rays were also concentrated on the object by means of a second plano-convex lens placed in the direct line of light after the manner of a modern substage condenser. The device is a clumsy one and never seems to have attained popularity, though the custom of fixing the

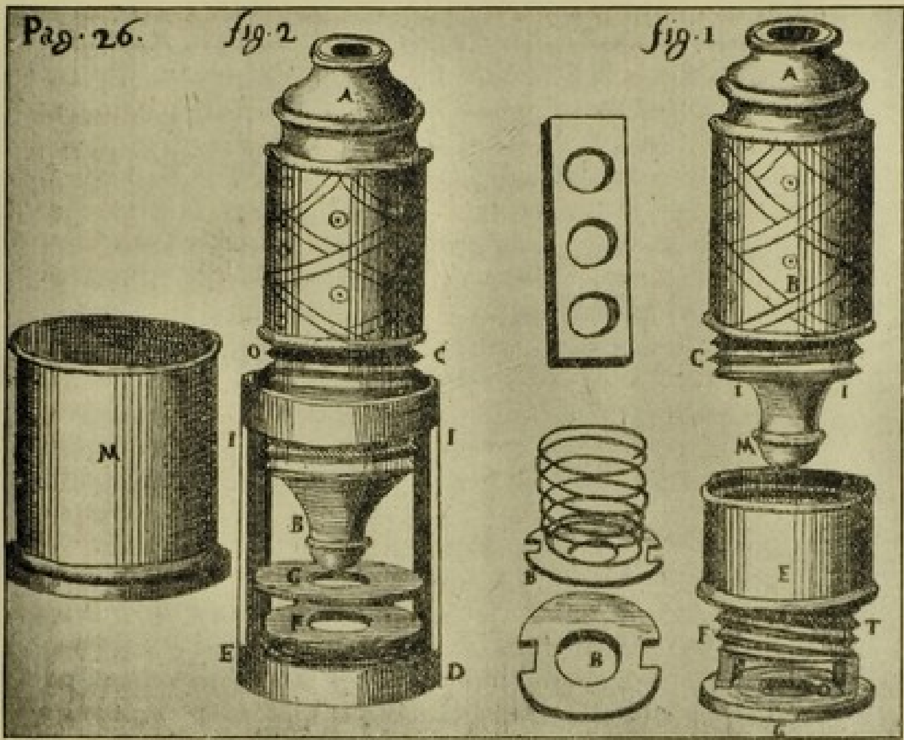


Fig. 15.

Kircher's compound microscope. (From Zahn.)

objective in the centre of a concave reflecting surface was temporarily revived in the eighteenth century.

A practical microscopist of early date with some knowledge of optical principles was Athanasius Kircher (fig. 14), whose observations we shall presently discuss. Kircher's first microscopical work appears to have been done with a simple instrument given to him by Cardinal Giovanni Carlo, son of Cosimo Medici II[1] (fig. 2). But he must have

[1] Athanasius Kircher, "Ars Magna Lucis et Umbrae," Rome, 1646, p. 835.

understood clearly enough the principles of the compound instrument from the works of Fontana and Scheiner, both of whom he quotes. For the "experiments" which he details in a later volume, the famous "Scrutinium Pestis" of 1658, he apparently used the compound microscope which was figured after his death by Buonanni and others (fig. 15). This microscope consisted of a rigid tube, with a lens at each end. The focus was obtained by screwing the tube up and down in a vertical stand. Later an increased refinement was secured with a second adjustment and the illumination was improved by a substage

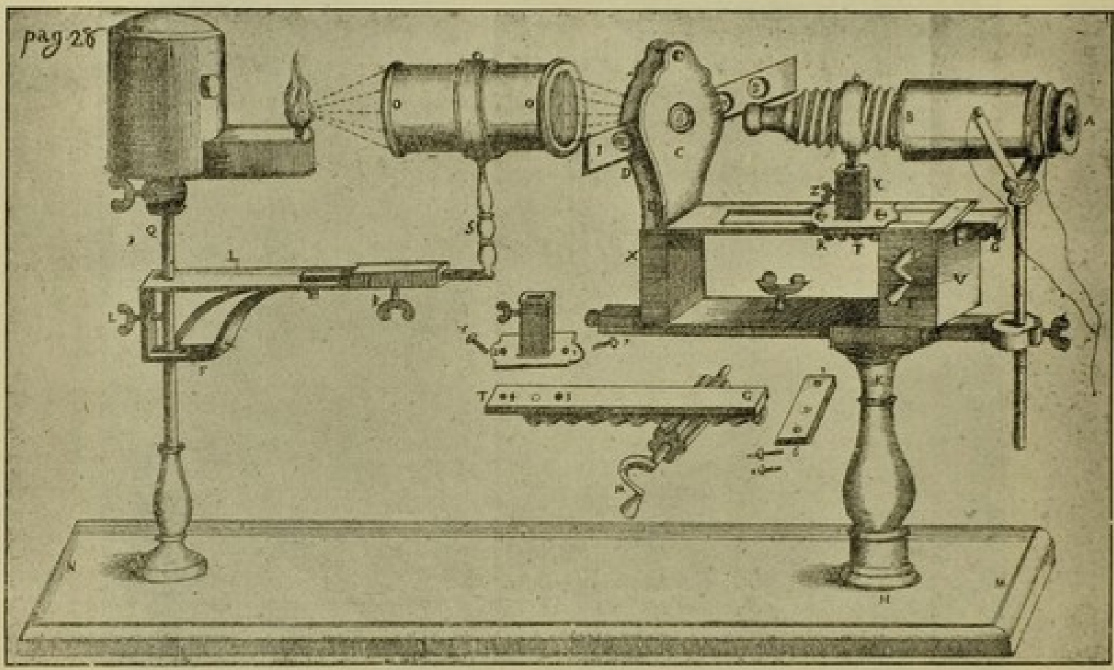


FIG. 16.

Kircher's compound microscope adapted with coarse and fine adjustment and substage condenser. (From Zahn.)

condenser, the instrument being used in a horizontal position[1] (fig. 16). Malpighi saw the circulation of the blood on the surface of the frog's lung by means of a compound microscope and Hooke had constructed a serviceable and elegant compound apparatus with an objective of very short focal length before the publication of his "Micrographia" in the year 1665 (fig. 17). He figures the instrument as provided with a condensing apparatus for concentrating either the sun's rays or those

[1] Philippo Buonanni, "Museum Kircherianum," Rome, 1709.

of an attached lamp. Microscopes similar to those of Kircher and of Hooke may still be seen in a state of good preservation in the Galileo Museum at Florence. Kircher's own instruments, however, have completely disappeared from the Museo Kircheriano at Rome.

Nehemiah Grew, in the Catalogue of the Museum of the Royal Society in 1681, describes among the objects there deposited a simple microscope as well as "A large Microscope with three Glasses, and

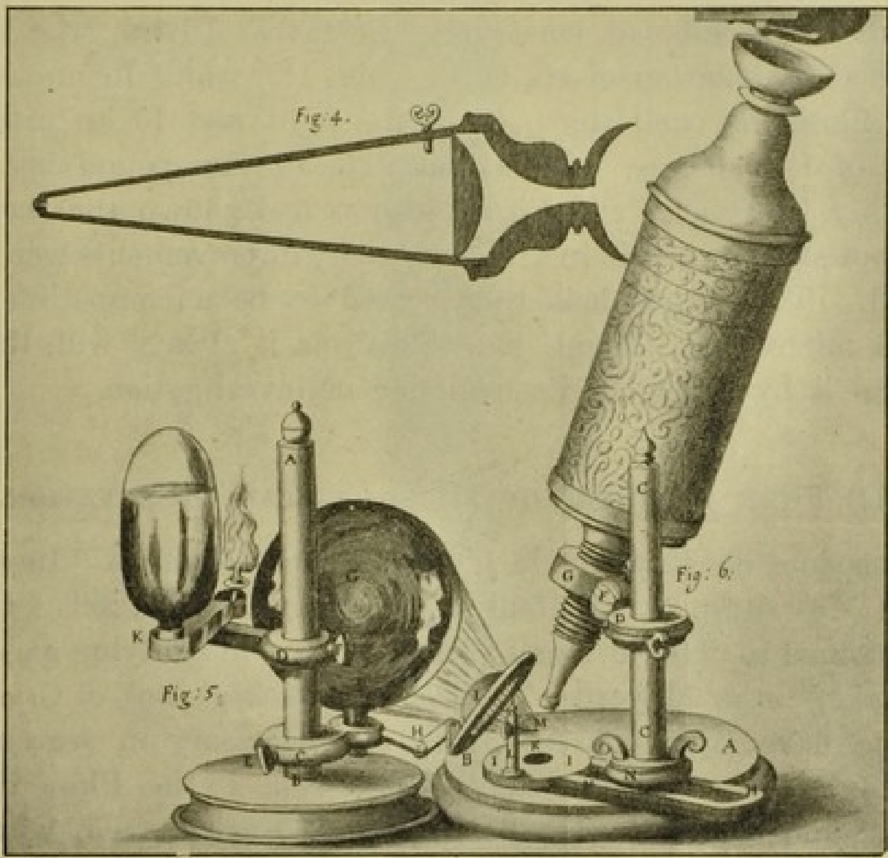


FIG. 17.

Hooke's microscope. (From "Micrographia," 1665.)

several Screws to fit it for all manner of positions. It magnifies the Area of the object to above a hundred times the extent thereof to the bare Eye." He distinguishes between the uses of the two types of microscope and tells us that "the advantage of one with more Glasses, is that it takes in a bigger object, or a greater part of it. Of one single Glass, that it shews the Object clearer. So that to have a distinct representation of it, 'tis convenient to make use of both." He goes on to tell us that "of the latter kind, I have seen several made by

Mr. John Malling in this City (London), not only with melted, but with Ground-Glasses so very small, that one of these Ground-Glasses being weighed in the Assay-Scales in the Tower, was found not above the fourscorth part of a Grain. The Diametre or Chord $\frac{1}{25}$th part of an inch. Another so small, that those scales were not nice enough to weigh it. The Chord hereof to that of the former is as two to three. These are the clearest and best that ever I saw."

The early microscopist who seems to have best grasped the principles and possibilities of the compound microscope and who realized the effect of a number of combined lenses was Eustachio Divini, who in 1663 was using a combination of six lenses[1] (fig. 18), while Johannes Zahn, in 1685,[2] illustrates well the path of the light rays in an instrument composed of four lenses. After that date the compound instrument rose steadily in favour, and after Newton had shown the theoretical possibility of an achromatic instrument, many improvements were slowly introduced. The simple lens thus ceased to be a competitor of the compound microscope, though it retained, as it always will, the value assigned to it by Grew, in its own line of investigation.

(III) Some Pioneers of Microscopical Observation.

Sir Theodore de Mayerne, in his preface to Mouffet's "Insectorum Theatrum"[3] (written about 1590 and published 1634), tells us how he was accustomed to observe small insects with a magnifying glass. "If you will take," says Mayerne, "lenticular optick glasses of Crystal (for though you have Lynx his eyes, they are necessary in searching for Atoms) . . . you will admire to see . . . the Fleas that are curasheers, and their . . . hollow trunk to torture men, which is a bitter plague to maids, . . . you shall see the eyes of the Lice sticking forth, and their horns, their bodies crannied all over, their whole sub-

[1] Eustachio Divini, "Lettera all Ill^{mo} Sig. Conte Carl, Antonio Manzini. Si raggaglia di un nuovo lavoro e componimento di Lenti, che servono à Occhialoni ò semplici, ò composti," Rome, 1663.

[2] Joannes Zahn, "Oculus artificiales, Teledioptricus, sive Telescopium," Herbipoli, 1685, p. 174.

[3] Thomas Mouffet, "Insectorum sive Minimorum Animalium Theatrum." The original MS., written about 1590, is now in the British Museum (Sloane MS., 4014, with engraved portrait). It fell into the hands of Mayerne and was published by him in 1634. A charmingly translated English version of the work and of Mayerne's preface, from which the above quotation is made, appeared from the hand of J(ohn) R(owland) in 1658 as "The Theatre of Insects or lesser living creatures."

stance diaphanous, and, through that, the motion of their heart and blood as if it floted in *Euripus* . . . Also little Handworms, which are indivisible, they are so small, being with a needle prickt forth from their trenches near the pool of water which they have made in the skin, and being laid upon one's nail, will discover by the sunlight their red heads and feet they creep withal." Mouffet himself refers to these acari

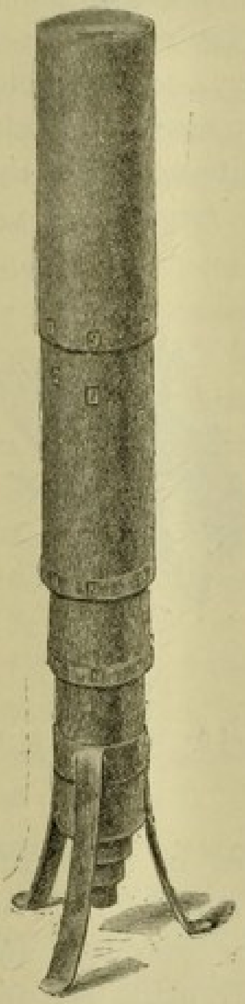


FIG. 18.

Microscope believed to be that of Eustachio Divini (1667). The body was constructed of cardboard and was provided with three draw tubes. This instrument was described as being in the Museo Copernicano at Rome by the late Mr. Mayall, in 1886. (Reproduction by kind permission of Sir Frank Crisp.)

as "the smallest of living creatures." He compares them to the mites of cheese, and correctly distinguishes them from the Pediculi. It is still doubtful how long before Mayerne the itch mite was investigated by means of magnifying glasses.

The earliest illustrated publication for which there is any evidence that a magnifying glass was used is by Hoefnagel and appeared at Frankfort in 1592.[1] The work consists merely of a series of copper plates of objects of natural history, but they are engraved with extraordinary beauty and accuracy, and some of them are enlarged in greater detail than would appear possible with the unaided eye. These remarkable figures are stated to have been drawn by a youth, aged 17. We reproduce here his magnified figure of the domestic fly (fig. 19).

In the first third of the seventeenth century, and before the period of true microscopic discovery, considerable attention was paid to the minute structure of natural objects, curiosity being aroused by attempts to discover with the magnifying glass the "atoms" comprising the minute structure of matter. One of the very earliest scientific workers

Fig. 19.

Enlarged figure of fly, as drawn by Hoefnagel, 1592.

with the microscope, inspired by such influences, was the noble and unfortunate Federigo Cesi, Duke of Aquasparta (1590-1629), the companion of Galileo and the president and founder of the Academia dei Lincei. Cesi was already using the instrument with effect before 1628. His microscopic skill is attested by his contemporary and associate, Johannes Faber (1578-1640), whose remarks on the subject drew the attention of our own Sir Thomas Browne (1604-82). In an interesting passage published in 1646,[2] showing larger powers of

[1] The title page is worded as follows: "Archetypa studiaque patris Georgii Hoefnagelii. Jacobus F. genio duce ab ipso scalpta, omnibus philomusis amicé D: ac perbenigné communicat. Ann: sal: XCII. Aetat: XVII. Frankfort a/M."

[2] Sir Thomas Browne, "Pseudodoxia Epidemica, or Enquiries into very many received Tenents and commonly presumed Truths," Lond., 1646, Book II, chap. vii, 3.

scientific judgment than is perhaps usually placed to the credit of the great stylist, Browne writes as follows concerning the sporangia of ferns: "Whether those little dusty particles, upon the lower side of the leaves be seeds and seminal parts . . . we have not yet been able to determine by any germination . . . from them when they have been sown on purpose . . . But by the help of Magnifying Glasses, we find these dusty Atoms to be round at first and fully representing seeds, out of which at last proceed little mites, almost invisible; so that such as are old stand open, as being emptied of some bodies formerly included, which though discernible in Hartstongue, is more notoriously discoverable in some differences of Brake or Fern. *But exquisite Microscopes and Magnifying Glasses have at last cleared this doubt, whereby long ago the noble Fredericus Caesius beheld the dust of Polypodi as bigg as Pepper corns;* and as Johannes Faber testifieth, made draughts on paper of such kind of seeds, as big as his Glasses represented them, and set them down as such plants under the Classis of Herbae Tergifoetae, as may be observed in his notable Botanical Fables."[1] Fragments of Cesi's herbarium still exist in Rome, but I have searched these without finding the figures to which Faber and Browne refer.

One of the best and most accurate early pieces of microscopic research was published in 1644 at Palermo by the Sicilian Hodierna.[2] This acute observer applied himself to the investigation of the eyes of insects, and his description of the eye of the fly is surprisingly fresh and good (fig. 20). "AB represents the entire head of the animal cut off from the rest of the body. It may here be seen that the head is all eyes, prominent and without lids, lashes or brows. It is plumed with hairs like that of an ostrich and has two little pear-shaped bodies hanging from the middle of the forehead. The proboscis which arises from the snout can be extended freely and stretched forth to suck up humours and can afterwards be directed back through the mouth to be taken into the gullet. This instrument nature has given the creature according to its need, for

[1] This passage is a paraphrase of one of Johannes Faber (1587-1640), physician to Urban VIII. Faber produced at Rome, in 1628, a work entitled "Animalia Mexicana." Browne's quotation is taken from page 757 of Faber's work, which was, in fact, actually printed before that of Cesi. Cesi's "Phytosophicarum Tabularum ex Frontispiciis Naturis Theatri," was completed in 1628, but was not published until 1630, after the author's death. It has been partially reprinted by Pirotta (Rome, 1904). I have been unable to trace the passage in Pirotta's reprint or in the editions of 1649 or 1651. The original edition of 1630 I have not seen.

[2] Giambattista Hodierna, "L'occhio della mosca discorso fisico intorno all'anatomia dell'occhio in tutti gl'animali anulosi, detti insetti," Palermo, 1644.

it is without a neck and cannot stretch forth its head to obtain its food, as is also the case with the elephant. C represents the whole eye cut off from the head AB on which can be seen more than thirty thousand little figures (quadretti) imprinted on the surface of the red cornea. D represents half an eye cut from the surface to the centre, so that the disposition of the crystalline structures can be seen. The crystalline structures, with their bases on the surface of the cornea, pass in a pyramidal fashion to end on the little tunic of the Uvea. This occupies the centre of the eye and in its interior the cerebral substance is enclosed. E is a white mulberry fruit which resembles the fly's eye in its similar disposition of facets as does also the strawberry represented at F."

One of the very first to collect observations made by the aid of the compound microscope was Francisco Fontana, whom we have already

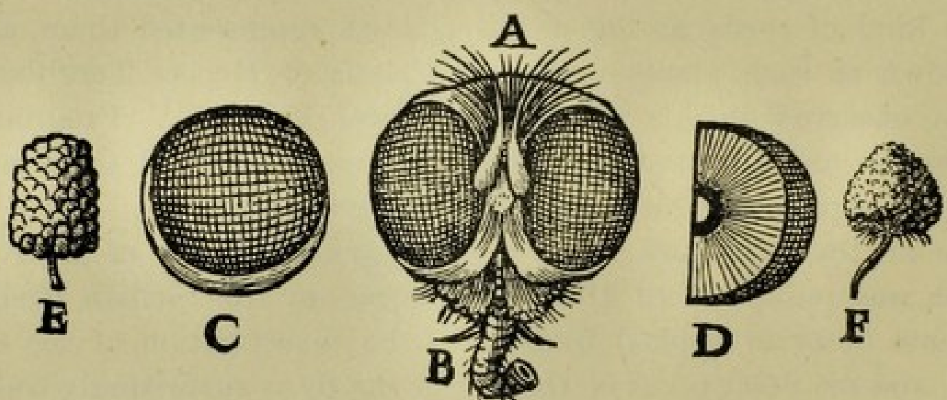


Fig. 20.
The fly's eye, after Hodierna, 1644.

considered among the pioneer constructors of the instrument. His tractate on the microscope (1646) contains a terminal chapter of four pages in which is briefly set forth a small series of observations on the mites in cheese, on the structure of the flea, the ant and the fly, and on other subjects, including the human body. We give here an example of his observations: "On the creatures that arise in powdery cheese." "The powder examined by means of this instrument does not present the aspect of dust, but teems with animalcula . . . It can be seen that these creatures have claws and talons and are furnished with eyes. The whole surface of their body is beautifully and distinctly coloured in such sort as I have never before seen, and which indeed, cannot be seen without wonder. They may be observed to crawl, eat and move and are equal in apparent size to a man's nail. Moreover, their backs are all spiny and pricked out with various star-like markings and surrounded by a rampart of hairs, all of such a marvellous kind that you would say they are a work of art rather than of nature."

Probably, the first practical physician who used a microscope in the course of his profession was Pierre Borel (1620-71). This versatile and gifted man, the son of a mathematician, struggled through youthful poverty and adversity to a very prominent position in the intellectual life of France.[1] Borel himself acquired considerable grasp of mathematical principles and was an ardent follower of Descartes. He was certainly in possession of a microscope and understood its uses before 1649.[2] His "Historiarum et Observationum Medico-Physicarum" of 1653 is, we believe, the first medical work involving the use of the microscope,[3] and the following quotation from it suggests that he had already, at that early date, obtained a view of the blood corpuscles.

"On Whale-shaped Insects in Human Blood (Century III, Observation 4).—Animals of the shape of whales or dolphins swim in the human blood as in a red ocean. . . . These creatures, it may be supposed (since they themselves lack feet) were formed for the bodily use of the more perfect animals within which they are themselves contained, and that they should consume the depraved elements of the blood.[4] If you would like to see these, take a sheep or ox liver, cut it into small portions and place it in water, teasing and separating it with your hands, and you will see many such animals escaping from them, nor will they be destitute of movement if the liver is fresh. They lurk in the large veins, and I think that they are those worms which are found in the stomach, being transformed when they change their position."

[1] A short account of the life of Borel is prefixed to "Les Antiquités de Castres," Paris, 1868, a reprint by C. Pradel of a work by Borel, published in 1649 (see following note).

[2] In a small volume entitled "Les Antiquités, Raretés, Plantes, Minéraux et autres choses considérables de la Ville, and Comté de Castres d'Albigeois," Castres, 1649, is an appendix consisting of a catalogue of Borel's museum. Among the objects mentioned are mirrors concave and convex, burning glasses, and also "De lunettes à la puce, ou *microscopes* qui grossissent fort les objets. De lunettes de multiplication, et pour approcher les objets," p. 147. Hoefer's "Nouvelle Biographie universelle" refers to an earlier edition of this catalogue, dated 1645 (when Borel was only 25), which we have not seen.

[3] Pierre Borel, "Historiarum et Observationum Medico-physicarum Centuria, prima [et secunda]," Castres, 1653. Our authority for the existence of this edition, which we have not seen, is Hoefer's "Nouvelle Biographie Universelle." We have ourselves used and quoted the Paris edition of 1656. There were several subsequent editions.

[4] The language of Borel is not very clear, and it is possible that he had been examining small clots rather than blood corpuscles. We incline, however, to the latter view.

Again in a later observation[1] he gives us a glimpse of tissue structure. "The heart, kidneys, testicles, liver, lungs, and other parenchymatous organs," he says, "you will find to be full of little structures (organula) and they are like sieves by means of which Nature arranges the various substances according to the shape of the holes. Passage is thus given only to atoms of a certain shape." And lastly he prophesies the medical application of his instrument. "These microscopes," he writes, "may be used in new matters in the observation of the sick, e.g. to observe change of colour or the generation of insects."[2]

In 1655 Borel issued a work on the telescope with which is bound up a series of one hundred microscopic observations, mainly on minute insects, with a few crude illustrations.[3] The separate issue of these microscopic observations a few months later constitutes the first book devoted to microscopy.

FIG. 21.

Acarus scabiei, as pictured by August Hauptmann, 1657.

We should briefly mention here August Hauptmann, a credulous writer, whose ingenuity was accustomed to outrun his judgment. To him belongs, however, the credit of being the first to figure a separate microscopic or rather submicroscopic organism[4]—viz., the *Acarus scabiei*. We give from a work of 1657 his representation of the animal, which the reader would probably not recognize without its context (fig. 21).

In many ways the most striking of these early microscopic workers is Athanasius Kircher. Impeded rather than helped by a vast learn-

[1] "Observationum Microscopicarum Centuria," The Hague, 1656, Obs. 76.

[2] "Observationum Microscopicarum Centuria," Obs. 83.

[3] Pierre Borel, "De vero Telescopii Inventore cum brevi omnium conspicilliorum historia . . . Accessit etiam Centuria Observationum Microscopicarum," The Hague, 1655. The separate title-page of the microscopic observations bears the date 1656.

[4] August Hauptmann, "Warmer Bad und Wasser Schaltz," Frankfort, 1657.

ing, and befogged by a method of writing from which the reader needs to excavate the meaning, he is yet an author who exercised wide influence on his contemporaries. Kircher was born in 1601 near Fulda, and was educated at the school of the Jesuit fathers in that town. He was received into the Order of Jesus at the Archi-episcopal city of Mainz, and later became Professor at the neighbouring University of Würzburg, which had been refounded some forty years previously. In the early seventeenth century Würzburg was the stronghold of the Jesuits in Germany, and its University was largely frequented by Catholic students. In 1631, during the Thirty Years' War, so disastrous to German academic life, Gustavus Adolphus, championing the Protestant cause, occupied Würzburg. The University became disorganized and Kircher fled to Avignon, whence four years later he proceeded to Rome under the protection of Cardinal Barberini, whose brother, Urban VIII, then occupied the Papal throne. This pontiff, who will go down to posterity for the share he took in the condemnation of Galileo, had in 1627 established in Rome the celebrated "College of the Propaganda" for the education of missionaries, and to this institution Kircher became attached for eight years as professor of mathematics. Resigning in 1643, he spent the remainder of his long life in the study of archæological and scientific subjects under the protection of members of the wealthy families of the Barberini and the Medici. Through his relationship with the College of the Propaganda as well as with the priests of his own Order, Kircher was placed in an especially favourable position to obtain from all parts of the world material and information on the subjects of his study. The valuable collection that he was thus able to gather he bequeathed to the College on his death in 1680.[1] This collection has been several times described and figured.

The successive appearance of Kircher's works was awaited with eager interest by the learned and curious throughout the world. Few men can have spent so busy a life as the old Jesuit. The actual physical labour of writing the endless series of works to which his name is attached might well appal a strenuous modern journalist; treatises on magnetism, a design for a calculating machine, works on optics, a history or account of the plague, monographs on philology and acoustics, theological tracts, an attempt at a universal script, a vast

[1] It formed the nucleus of the Museo Kircheriano, now absorbed into the Museo Nazionale at Rome. His microscopes have apparently been lost, although some of his astronomical instruments are still preserved at the Collegio Romano.

tome on volcanoes, mathematical works, an essay on the philosopher's stone, an attempt at a Coptic grammar, a work on Egyptian antiquities and hieroglyphics, and an account of China flowed from his pen in rapid succession. In most of his works Kircher is quite uncritical and lacking in judgment, though he displays some originality, combined with a

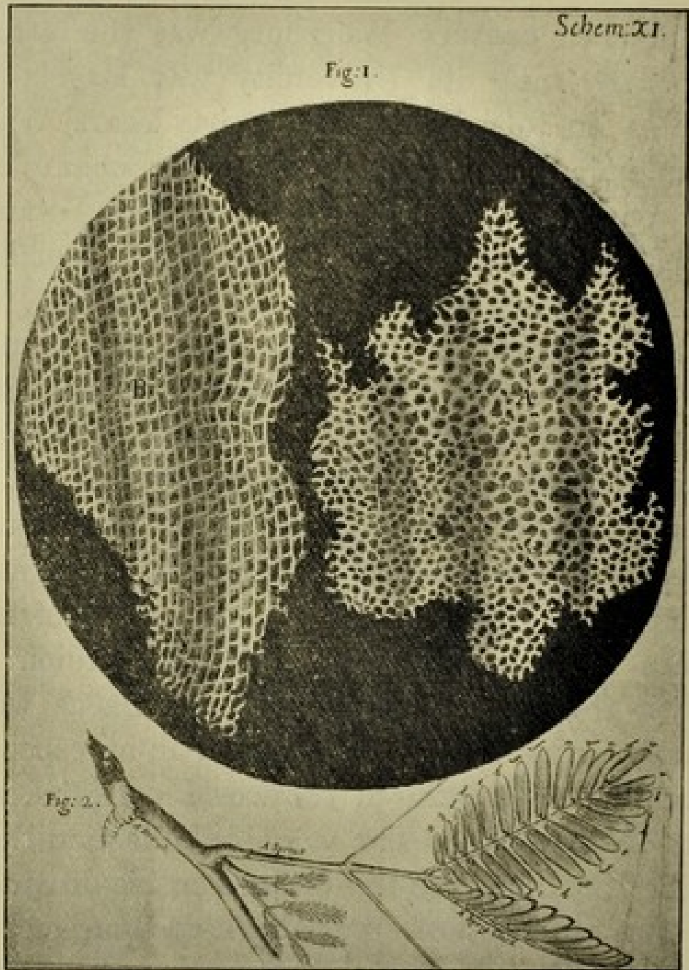


FIG. 22.

Plant cells. (From Hooke's "Micrographia," 1665.) This is probably the earliest work in which cells are figured.

remarkable power of absorbing both information and misinformation. In his work on the Plague,[1] however, he shows genuine insight, and gains a clear though distorted view of organisms of minute size acting

[1] "Scrutinium Physico-Medicum contagiosae Luis, quae Pestis dictitur quo origo, causae, signa, prognostica Pestis, nec non involentes malignantis Naturae effectus, qui statis temporibus, caelestium influxuum, virtute et efficacea, tum in elementis; tum in epidemiis hominum animantiumque morbis elucescunt, una cum appropriatis remediorum Antidotis nova doctrina in lucem eruuntur," dedicated to Pope Alexander VII, Rome, 1658.

as the vehicles of contagion. Being himself a practical microscopist, he was aware of the difficulties and possibilities of the method. Thus, although his work is characterized by total disregard of "control" observations, and is undeniably marred by his credulity, he yet shows a first-hand acquaintance with minute life, which proves that he had industriously explored the microscopic world within the scope of his own rough instruments. How he managed with his endless

Novum Microſcopium Dn: Iosephi Campani ejusque uſus.

FIG. 23.

The earliest figure illustrating the use of the microscope in medicine, from the "Acta Eruditorum," of 1686. To the right is seen a figure examining an ulcer with the microscope while the light of a candle is focused by means of a lens in the hand of the female figure. To the left of this group another method of using the instrument is illustrated, and to the extreme left is an enlarged detail of the microscope fixed in a stand.

pre-occupations to find time for such studies is a lasting mystery, but there seems to me to be no reasonable doubt that he did habitually examine forms beyond the range of unaided vision, including infusoria. The organisms which he describes as occurring in the blood of the plague-stricken were, however, not bacteria, but either pus corpuscles or rouleaux of blood cells.

It is impossible here to discuss in detail the complicated question of Kircher's conception of the nature of infection, or the sources from which this conception was derived.[1] It will suffice to say, briefly, that he regards the essence of the disease as a "putridity of the humours," and putridity he regards as a condition produced from "semina" thrown off according to the then prevalent doctrine of "effluvia" from other putrid bodies. "Air, water and earth," he tells us, "teem with innumerable insects capable of ocular demonstration. Everyone knows that decomposing bodies breed worms, but only since the wonderful discovery of the microscope has it been known that every putrid body swarms with innumerable vermicules, a statement which I should not have believed had I not tested its truth by experiments during many years." There follows an account of a series of experiments, from which we have selected the following:—

"Experiment I: Take a piece of meat which you leave exposed by night until the following dawn to the lunar moisture. Then examine it carefully with the smicroscope and you will find the contracted putridity to have been altered by the moon into innumerable wormlets of diverse size, which, however, would escape the sharpness of vision without a good smicroscope. . . . The same is true of cheese, milk, vinegar and similar bodies of a putrefiable nature. The smicroscope, however, must be no ordinary one but constructed with no less skill than diligence, as is mine which represents objects a thousand times greater than their true size.

"Experiment II: If you cut up a snake into small parts and macerate it with rain water, and then expose it for several days to the sun and again bury it under the earth for a whole day and night, and lastly examine the parts, separated and softened by putridity, by means of a smicroscope, you will find the whole mass swarm with innumerable little multiplying serpents so that even the sharpest eyes cannot count them.

"Experiment III: Many authors claim that unwashed sage is injurious . . . but I have discovered the cause of this. For when, by means of the smicroscope, I minutely examined the nature of this plant, I found the back of the leaves entirely covered by raised work, as with

[1] The subject is discussed in an essay by the present writer on "The Doctrine of Contagium Vivum," in the *Proceedings of the Seventeenth International Medical Congress*, 1913 (Historical Section).

the figure of a spider's web, and within the web appeared infinitesimal animalcules, which moving constantly came out of little buds or eggs. . . .

"Experiment IV: If you examine a particle of rotten wood under the smicroscope, you will see an immense progeny of tiny worms, some with horns, some with wings, others with many feet. They have little black dots of eyes. . . What must their little livers and stomachs, their tendons and nerves be like?"

With Athanasius Kircher we leave the actual pioneer period of microscopy and enter on what may be called the classical epoch of our subject. This field has been well covered by historical writers, and the literature is more accessible. Here, therefore, we may part with the reader in the goodly company of Robert Hooke, Nehemiah Grew, Anthony Leeuwenhoeck, Jan Swammerdam and Marcello Malpighi.

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