NEW HISTORY OF THE OPTICAL MICROSCOPE

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After a résumé of the history of the compound microscope that many historians of science have dealt with, the author points out that until 1840 real microscopy was carried out by means of the simple microscope although the compound microscope was being continually improved by infatuated pioneers. The 'father of microscopy', A. van Leeuwenhoek, constructed and used only simple microscopes. Also recent measurements have shown that until 1840 all compound microscopes were decidedly inferior to the simple one. In 1840 the application by G. B. Amici of the frontal hemispherical lens to the objective for microscopes allowed the compound microscope to prevail over the simple one. This new history of microscopy has led to set the problem why microscopy with a simple microscope (which is composed notoriously either of a converging lens or of a concave mirror) had not been practised in the centuries prior to the seventeenth, inasmuch as concave mirrors were known as early as the fourth century B.C. and lenses since the thirteenth, and already at the beginning of the sixteenth century G. Rucellai had published the anatomy of the bee carried out by means of a concave mirror. The reasons of this enormous delay in the practice of microscopy are to be found in the ideas predominating in ancient and medieval philosophy.

A great number of eminent specialists in history of science have surveyed the history of the microscope and chronological researches have been carried out with such wealth of data and with such accuracy that it would seem that the argument had been thoroughly and definitely settled. However, as in the last twenty years my researches on the evolution of optics, during the ancient and Middle Ages and also in the later centuries, have put into evidence some historical and philosophical phenomena over which a thick veil of oblivion had been drawn, noticeable effects of my researches have been felt also in side branches of optics, and particularly in the history of the microscope. Since these effects are of interest, especially from a philosophical point of view but also in general, I think it will be of interest to briefly summarize the 'New History of the Optical Microscope' in order to point out how it fills some considerable gaps in the history that was known up to now.

This history, as I have said, has been outlined with care and great competence by noteworthy historians, but leaves a side open to criticism.

(1) It concentrates its attention on the 'compound microscope' and considers the simple microscope as a device too simple to have a right to be placed in the history of science and technique.

(2) While historians of the microscope have often devoted great attention and research work to the biological and naturalistic applications of the microscope, they have not bothered to frame the employment of the instrument within the fundamental optical notions of the epochs in which it was used.

(3) Several well-known and very strange circumstances have been overlooked not only without explaining them but even without bringing them into evidence, whereas they can be exhaustively explained when the history of the microscope is thoroughly examined in the general frame of antique and medieval optics.

The soundness of this criticism will become evident following my narration. This will be divided into two parts: in the first the history of the 'compound microscope' will be summarized in its general lines, as it can be found already related in numerous other publications. The purpose of this summary is just to emphasize the lack of some considerations and the setting of some questions, to which an answer can be given with the information and the details pointed out in the second part of this memoir. Therefore the first part will have a prevailingly technical background and the second will have a historical-philosophical character.

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The question which has received an answer several times is: who constructed the first compound microscope? In this regard some pretensions to priority of the Dutchman Drebbel have been brought forth against Galileo, and occasionally the argument is taken up, although the decision concerning Galileo's priority is by now unquestionable.

The brief indication regarding this will perhaps eliminate all doubts. When in 1609 Galileo constructed so many telescopes for telescopic observations, that he had also applied an optical system, consisting of an objective lens and an eyepiece for the observation of very near objects, is testified in a passage of a writing by the Scotchman John Wodderborn, a pupil of Galileo, in an answer of his, in June, 1610, to the libel written by Martin Horky slandering the telescope. Shortly after, a brief writing was published, entitled 'Quatuor problematum quae Martinus Horky contra Nuntium Sidereum de quatuor planetis novis disputanda proposuit. Confutatio per Johannem Vodderbornium'. The preface, signed by the English Ambassador in Venice, is dated 16th October, 1610. The interesting passage is the following [1]:

'... Now I will not try to explain the excellence of this marvellous instrument: the sense itself is a very reliable judge of its effective capacities. Because, at a distance of one thousand and more paces, when you would not even think that an object exists, by employing the telescope, immediately you can see with all certainty that it is Socrates, the son of Sophroniscus, who is coming towards you: but time and the daily discovery of new things will teach us how remarkably the telescope carries out its function, in fact its whole beauty consists exactly in this. A few days ago I heard the author himself (i.e. Galileo) relate to His Excellency Cremonino, aulic philosopher, several things very worthy to be known, and among others, the way in which he can distinguish with great precision the organs, movements and sensations of very tiny animals, and in particular of a certain insect, that has both eyes covered by a very thick membrane, that, however, gives entry to the species of visible things through seven small openings, as through the iron helmet of a soldier . . .' *

There is thus no doubt that Galileo carried out microscopical observations with an optical system analogous to the one of the telescope, that is to say he had assembled a fine compound microscope since 1610.

But it is also certain that he soon lost interest in this kind of observation.

Now, two questions immediately come forth : why did all historians take such an interest in the invention of the compound microscope, and no one, at least as far as I know, cared to find out who had invented the simple microscope ? The question is entirely justified, because the step from the simple to the compound microscope is, so to say, a technical and secondary feature, whereas the great novelty consisted in applying the observation carried out by means of lenses to the study of the animal, vegetal and mineral kingdoms. Therefore the real history of microscopy should first establish who had accomplished this great step and then, in the second place, set the problem of finding out who had eventually brought microscopy an advantage by substituting a simple microscope with a compound one, admitting that this advantage had occurred. As we will presently see, beneath this there is a very great question.

The other problem, that also offers a certain interest, is the following: Why did Galileo lose interest in observations carried out by means of the compound microscope that, as Wodderborn informs us, he had already begun to use ?

In order to answer these questions it is well to go on with the history of the instrument.

Some compound microscope had been constructed and even employed, but without much success and also without any revolutionary results. The

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* '. . . Ego nunc admirabilis huius perspicilli perfectiones explanare non conabor: sensus ipse iudex est integerrimus circa objectum proprium. Quid, quod eminus mille passus et ultra, cum neque vivere judicares objectum, adhibito perspicillo, statim certo cognoscas, esse hunc Socratem Sophronisci filium venientem; sed tempus nos docebit et quotidianae novarum rerum detectiones, quam egregie perspicillum suo fungatur munere, nam in hoc tota omnia instrumenti sita est pulchritudo. Audiveram paucis ante diebus auctorem ipsum (that is to say, Galileo) Excellentissimo D. Cremonino purpurato philosopho varia narrantem, scitu dignissima et inter cetera, quomodo ille minimorum animantium organa, motus et sensus ex perspicillo ad unguem distinguat; in particulari autem de quodam insecto, quod utrumque habet oculum membrana crassiuscula vestitum, quae tamen, septem foraminibus ad instar larvae ferreae militis cataphracti terebrata, viam praebet speciebus visibilium . . .'

most interesting document from this point of view is Robert Hooke's *Micrographia* published in 1665. In the Museums of the History of Science very interesting collections of microscopes are to be seen, which had been constructed during the seventeenth, but above all during the eighteenth, century. A remarkable improvement from a technical viewpoint, but principally from an aesthetical point of view, can be noticed. But we notice that the mounting, initially consisting of wood and cardboard, gradually is substituted with metal; the stativ always the more resistant, the illumination device always the more powerful; but all in all the instrument maintains its characteristics of an object of luxury and not of a working-tool.

To an optical technician it is evident that an instrument that has an objective, consisting of a single lens and also the eyepiece consisting of one or two simple lenses, could not give very remarkable service. Enormous aberrations, especially chromatic, hindered the employment of elevated magnifications, if not at the risk of a complete confusion of images; a very scarce luminosity and difficulty in the handling made observations actually painful, besides their uselessness.

All these difficulties began to decrease and even to disappear when objectives began to be achromatized. However, this situation continued until the end of the eighteenth, and the beginning of the nineteenth, century. The most prominent opticians, especially English opticians, were giving much attention to the improvement of the microscope objective, and at the same time also the eyepiece and the stativ were improved.

Thus we come to the times of G. B. Amici (born in Modena, Italy, in 1786, died in Florence in 1863). As it is known he attempted at first to construct achromatic microscopes by employing a concave mirror objective, thus applying the criterium that Isaac Newton had devised in the field of astronomical instruments for the construction of achromatic telescopes. But later Amici resumed the construction of dioptric objectives, with numerous lenses of various optical glasses, such as crown and flint, that already then were produced in various qualities, and he obtained considerable improvements, until at last he was able to construct objectives having a hemispherical frontal lens and also immersion objectives.

Until now no documentation was known of this great innovation, the importance of which will presently be pointed out more in detail. No one has asserted the priority of it and everywhere it was claimed to be the work of G. B. Amici, but without any proofs.

As in 1963 the centenary of Amici's death recurred, some researches were carried out in Amici's voluminous and copious correspondence, now belonging to the Estense Library of Modena, Amici's birthplace, together with numerous other manuscripts of his. Among the many letters there is a copy of a letter written by Amici to F. O. Mossotti on 25th October, 1855.

Amici was then Director of the Museum of Natural History in Florence and Mossotti, Professor of Rational Mechanics at the Pisa University, and was famous for his ability in the calculation of optical systems, as can be seen in the classical book he has left us.

The following passage quoted from the above-said letter[2] is particularly important: ' . . . You are right to believe that with two glasses of different dispersion power or even better with three glasses, colours can be destroyed in a tolerable degree and good compound objective lenses can be constructed. The objective lenses of my microscopes consisting of six lenses, three of crown and three of flint, prove to be achromatic. But I have found that the series consisting of three pairs of lenses, as I have said, were not the best fit to obtain the greater magnifications, particularly on account of the lower doublet towards the object being too thick, which does not allow the making of the focal distance of the system very small and its aperture very great. I then thought of replacing the lower doublets with a simple lens, i.e. half of a sphere of any transparent substance whatsoever, either crown, or flint, balas ruby, diamonds, fused rock crystal, etc., and eliminate their aberrations by the two upper doublets conveniently designed. For this purpose I needed a flint of very great dispersion power that I was able to obtain from Faraday through Airy's mediation. The English opticians laughed at my request, but when in 1844 in London I demonstrated the superiority of the new construction, they at once set to imitate it and so did also the Americans. The French, not paying attention to it and not understanding the improvement, were left behind the others . . .'

The letter goes on and enters into technical and constructive particulars that are very interesting to the specialists in the calculation of microscope objective lenses, but do not pertain to the discussion I am about to reach.

I have rapidly come to Amici's work, without mentioning other famous predecessors, especially of the second half of the eighteenth century, because it would be too long a list and would not be of great importance; but at this point we must recall Chevalier who, during the first half of the nineteenth century, in Paris, brought considerable improvements to his microscopes, although he never reached Amici's level.

After Amici there came Ernst Abbe's very interesting and also important studies at Jena; he was able to give an interferential theory of the formation of images in the microscope, a theory that was considered definitive until a few decades ago. Also Siedentopf's ultramicroscope had a certain renown, but principally the definitions of the so-called 'resolving power of the microscope' had importance in the history of the optical microscope besides the definition based precisely on Abbe's undulatory theory: of the limit that constitutes a sort of barrier against the penetration into the infinitely small by means of radiations capable of stimulating the human retina.

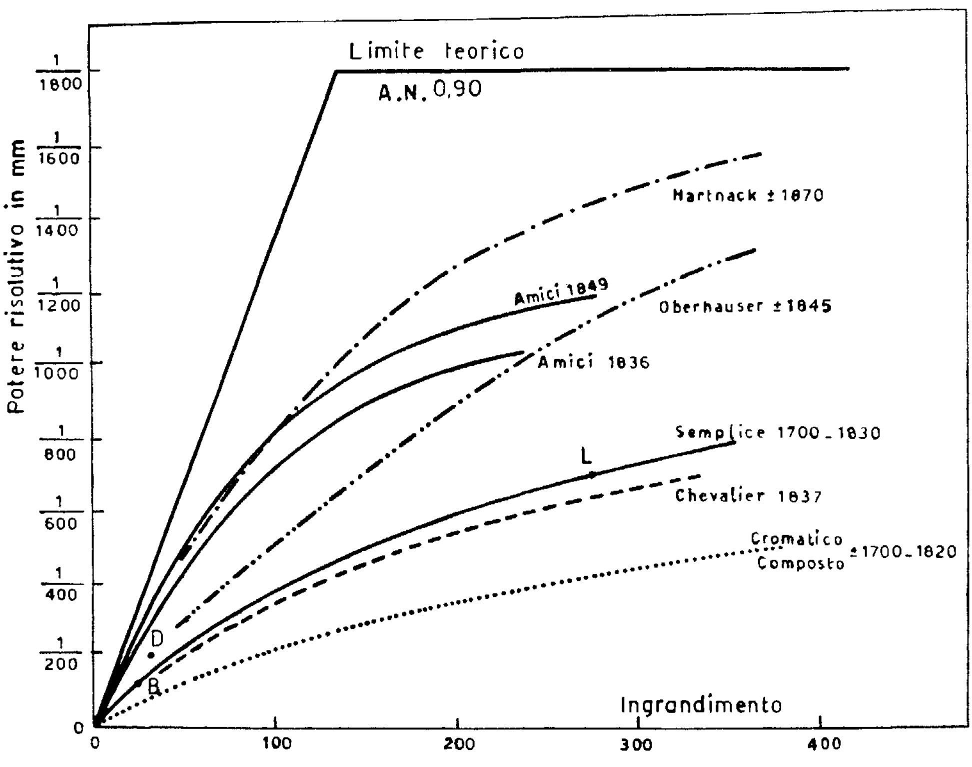
Substantially their limit has been reached by Amici's apparatuses; later improvements, such as observation in a dark field, the phase contrast and the interferential microscopy, represent very interesting techniques, and very useful to facilitate microscopical observation in special cases, but substantially they have not notably shifted the limit of the optical microscope's possibilities of penetration into the infinitely small.

A recent novelty is the 'energetic theory' of the resolving power that represents a clear advancement in respect to Abbe's theory. According to the new theory,[3] the 'resolving power of the microscope' considered, that is to say, as a feature of the instrument (or rather of its objective lens) independently from any other circumstance not belonging to the instrument itself is to be considered non-existent; if we accurately criticize the reasoning that brings to its definition, we will find that it is merely 'conventional', whereas the resolving power that is experimentally achieved with a given microscope depends from numerous factors, among which the structure of the objective lens is one alone and not even the most important. But first of all the useful energy of the source of illumination intervenes and afterwards the functioning of the optical condenser; then the observer's eye with its sensitiveness and acuity intervenes and other factors such as the duration of the observation, the knowledge concerning the preparation, the fatigue of the observer. The optical resolution came out as an exquisitely energetic phenomenon, and this represents a novelty that can bring also interesting developments.

But now I must leave aside this part of the technical and theoretical history of the microscope, and turn back to examine its nature and value.

As I have said, Galileo, after having carried out some observations with what was called the 'occhialino' (small eye-glass) ('occhiale' (eye-glass) at first indicated exactly what later was called 'telescope', considered as a 'special eye-glass which enables to see far away, enlarged and distinctly') was not interested any more in the microscope or in microscopical observations. With the acute spirit of observation with which he was endowed and with the 'good sense' that distinguished him, he at once knew how to estimate the slight efficiency of the instrument that he had already used for some observations, and he devoted himself instead to the great astronomical and philosophical questions hinged upon the observation of stars. Perhaps the fact that Galileo had no intention of devoting himself to investigations of a naturalistic character, also contributed to this decision. But it is certain that about a half of a century was still to go by, before microscopy had a real development. This was the work of a very interesting personage : Antony van Leeuwenhoek.

We will recall that he was born at Delft (Holland) in 1632 and therefore was hardly ten years old when Galileo died. At the age of sixteen he was working in a textile establishment where, it seems, he had learnt to use lenses to count the threads of the materials.[4] The most remarkable fact is that later he became an usher in a Government office and spent his time in waiting-rooms constructing microscopes and carrying out observations. Clifford Dobell has translated and studied all Leeuwenhoek's correspondence. What has emerged from it is that he was absolutely a self-taught man, lacking of any scientific culture and that he only knew the Dutch language. He did everything by himself with no help. Often he couldn't even find suitable words to properly describe the discoveries he was making with his microscopes. He carried out the strangest experiments, such as observing the conflagration of gunpowder through a microscope, and nearly lost his sight.



Plot of the resolving power (ordinates) against the magnification (abscissae) of the microscopes in charge of the Museum of the History of Science of Utrecht according to the measurements carried out by Dr. and Mrs. van Cittert.

Over 300 microscopes which have been constructed by him still exist. They consist of a tiny lens; the object was fixed to the point of a needle and a rudimental system of screws gave the possibility of bringing the object into focus of the lens. The measurements carried out on van Leeuwenhoek's lenses by H. Bakes in 1740 have given focal distances ranging between 5 mm and 1, 2 mm, i.e. capable of giving as many as 200 conventional magnifications. Using such inconvenient and difficult instruments, van Leeuwenhoek was able to obtain really admirable results in fineness, reliability and importance. His fame called the attention even of ruling monarchs; he received the visits of Charles II, George I and Queen Anne; in 1698 he showed Czar Peter I the circulation of blood in the tail of an eel.

But the most important thing to be remarked now is that a person like van Leeuwenhoek who had constructed and used hundreds of *simple* microscopes with so much success, working on them his whole long life (he died in 1723 at the great age of 91), never used a compound microscope, although it had been invented since over a century.

The explanation of this becomes quite evident if we technically study the performance of the compound microscope constructed in various epochs and still existing in numerous specimens in several museums of the history of science. In the 'Descriptive Catalogue of the Collection of Microscopes in charge of the Utrecht University Museum' P. H. van Cittert published an 'Introductive Historical Survey of the Resolving Power of the Microscope', in which, on the basis of many observations carried out by means of the rich collection of microscopes at his disposal, he demonstrated that the resolving power of the simple microscope was superior to that of the compound microscope in the whole period between the seventeenth and the first half of the nineteenth centuries. Only after the application by G. B. Amici of the hemispherical frontal lens to the objective for microscopes, the compound microscope came into prominence; Chevalier's microscopes (1837) were still inferior to the single one. Oberhäuser's (1847) definitely signed the beginning of the useful employment of the compound microscope. The diagram here unmistakably demonstrates the change that took place in the field of microscopy towards the middle of the nineteenth century.

Thus the history of microscopy may be synthetized as follows : microscopy, starting shortly after the middle of the seventeenth century, through the work of van Leeuwenhoek, rapidly established itself and developed using exclusively the simple microscope; in the meantime many attempts were made to improve the compound microscope, but without success; an advancement in this sense was made in the second half of the eighteenth century when achromatic objectives began to be constructed; but only towards the middle of the nineteenth century the compound microscope decidedly prevailed over the simple one after G. B. Amici had introduced the hemispherical frontal lens in the objective one. This last great innovation was followed by further improvements that brought the compound microscope to the theoretical limit of penetration in the microcosmos by means of optical radiations. The simple microscope was progressively reserved for less engaging operations, until it nearly disappeared out of circulation.

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Thus having reconstructed the history of the microscope, I will go on to the second part of this paper, and will begin by setting the following question: since microscopy originated with the simple microscope which consists of a single and simple converging lens, why did microscopy start only after the middle of the seventeenth century?

Lenses were known since long. Leaving aside some very questionable forerunners (it seems that they were already known by the Ayuredi, 2000 B.C., that a rock-crystal lens has been found in the ruins of Nineveh, that Seneca used to make observations through transparent spherical vases full of water, and Plutarch, Plinius, Svetonius, Galen, Jamblicus and others quote examples of lenses) it is a fact that Ibn-al-Haitan (more known by the vulgarized name of Alhazen) towards 1050 used glass hemispheres as magnifying lenses and Roger Bacon (English monk who lived between 1214 and 1294) speaks of them in his 'Opus Majus' that was presented to Clement IV in 1267. In any case starting from 1285 'glass lenses', i.e. converging lenses, were applied as eye-glasses for the correction of presbyopia. Magnifying lenses were used by Leonardo da Vinci (Codice F., folio 33, verso). Therefore there was an optical instrument that could make microscopy possible. Why was it not put into practice?

But there is even more. Also a concave mirror is a microscope. Now it is well known that concave mirrors were already studied in Euclid's 'Catoptrics', that is to say, twenty centuries before the seventeenth century. As these had actually been constructed and used, at least as burning mirrors, whoever had handled them and polished them must have noticed that they magnified images. Ptolemy, in the second century A.D., made a systematic study of the images that are given through concave mirrors, why then hadn't they been employed to practise microscopy?

The question has even more interest, if we recall that the Florentine Giovanni Rucellai published in 1523 a short poem entitled 'Bees', in which at the verses 963–995 we read:

'I had already set myself to make in these insects incisions
of many of their parts, that the Greek language calls Anatomy:
so much care I had of the small bees.
And it would seem incredible, if I were to narrate how some of
their small members are, which are almost invisible to our eyes;
but if I tell you the instrument and the way I proceeded, it
will not seem an impossible thing.
So if you want to know this way, take a good bright concave

mirror, in which the small shape of a child, just newly born, would seem to you a great giant; so you will see the image of the concave reflection multiplied by the metal, such that the bee seems a dragon or other beasts that Lybia brings us. Then you will see, as I saw, the organ articulated inside and out, its shape, arms, feet, hands, back, its feathered and gemmed wings, its proboscis or trunk, such as the Indian elephants have, with which it presses on the dewy foliage and takes up its babes.
Furthermore you can see that they have a hidden sword in a sheath, that Nature has given them for the salvation of themselves and of their ruler . . .' *

So even leaving aside all that regards the centuries previous to the thirteenth century A.D., it is a fact that since then both the catoptric and dioptric microscopes were available to scientists, but no one used them. When in 1523 Rucellai published his short poem describing what he had observed using a concave mirror for microscopical observations, no one considered it a miracle that finally the great idea had been realized of employing this technique to study Nature but, on the contrary, no one followed him.

The reason that Rucellai's innovation met with no success cannot be attributed to the modesty of the means of observation or to its scarce practicability. This justification could be put forth if the optical device had undergone criticism or had been carried out and exploited to the utmost and had given insignificant results unworthy of notice; but instead the possibilities, although very modest, were not even taken into consideration and Rucellai's work was simply forgotten.

If, however, microscopy did not start before the second half of the seventeenth century, it was not because the microscope was lacking, as it already existed and could have been immediately and easily put to use.

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* 'Io già mi posi a far di questi insetti
incision, per molti membri loro,
che chiama Anatomia la lingua greca:
tanta cura ebbi delle piccole api.
E parrebbe incredibil, s'io narrassi
alcuni lor membretti come stanno
che son quasi invisibili ai nostri occhi;
ma s'io ti dico l'istrumento e'l modo
ch'io tenni, non parrà impossibil cosa.
Dunque se vuoi saper questo tal modo,
prendi un bel specchio lucido e scavato,
in cui la picciol forma d'un fanciullo
ch'uscito sia pur or dal matern'alvo,
ti sembri nella vista un gran colosso;
Così vedrai moltiplicar la imago
dal concavo riflesso del metallo,
in guisa tal che l'ape sembra un drago
od altra bestia che la Libia mena.
Indi potrai veder, come vid'io,
l'organo dentro articulato e fuori,
la sua forma, le braccia, i piè, le mani,
la schena, le pennute e gemmate ale,
il nifolo o proboscide, come hanno
gl'indi elefanti, onde con esso finge
sul rugiadoso verde e prende i figli.
Ancor le vedi aver l'occulta spada
ne la vagina, che natura ha fatta
per la salute loro e del suo rege . . .'

It is a historical phenomenon of considerable importance and it really is strange that it has escaped the notice of all the historians of science who up to now had studied this argument. Its explanation is evident within the framework of ancient and medieval optics, as I have reconstructed it concerning the invention of eye-glasses and of the telescope.[5]

Prior to Galileo's achievements, philosophers and cultured people were decidedly hostile towards observations carried out by means of optical devices of any kind. Therefore the deepest scepticism was rooted in the minds of everyone and was explicitly practised and widespread by the luminaries of science and of philosophy of all schools. The terrible words that summarized this scepticism were attributed to Euclid: 'Non potest fieri scientia per visum solum', i.e. 'It is not possible to work out science by means of sight alone.' In conclusion one was always to be distrustful of what was seen, if it was not conditioned by the other senses, possibly by touch. The only useful sense that deserves complete faith (although at times also this sense had been found at fault) was touch. Sight had been put under the guardianship of touch.

It has not been difficult to reconstruct the reasons that caused such a deep and general distrust in the sense of sight. For centuries and centuries attempts to find the clue of the mechanism of vision had stumbled against unsurpassable difficulties, the theories that had been devised were so scarcely convincing and so queer, that they were open to a quantity of even elementary objections.

As can be seen in the above-mentioned literature, the principal theories were two: the theory of *visual rays*, coming out of the eyes to explore the outer world, and the theory of *species*, or *skins* or *simulacres* that were to be emitted by luminous or illuminated bodies, in all directions, and penetrate into the eyes through the pupil.

I can also add, briefly, that the theory of visual rays, upheld by mathematicians, who were interested in *perspective*, had dominated the world of science for over fifteen centuries, until the eleventh century A.D.; during that period, in fact, optics and perspective were often interchanged, one with the other. But when Alhazen, who lived during the eleventh century A.D., called attention on the known phenomenon of the persistence of the retinal images (as today is called the vision, prolonged in time, of the figure of a very intense source, such as the sun, even when one closes one's eyes after having stared at it for some time), the theory of visual rays was potentially demolished and the theory of the *species* prevailed; until then it had been followed by very few physicists.

I have said that the theory of visual rays had been *potentially* demolished, because in reality it continued to be used especially by mathematicians so that during the centuries between the eleventh and the sixteenth the greatest theoretical confusion reigned in optics.

It could not but negatively influence the faith in the functioning of vision in direct observation and still more in observation through optical devices, which showed images certainly not corresponding to real objects as they were indicated by touch. All the more so that many of the observations, carried out from a critical point of view by those who were attempting to settle this unfortunate theory, appeared always the more to be optical illusions.

It was only too natural that an organ, the functioning of which was unknown and had been found at fault more than once, should cause the loss of faith in it for ever. It was inevitable that teachers in the schools should hand down to their pupils the fruits of their experience, namely, that one was not to believe in the illusion of vision.

If this was the attitude of learned people towards direct vision, that is to say, carried out without any special optical means placed between the eye and the object, the distrust towards all optical devices must have been still greater, no matter whether they were catoptric, dioptric, plane or curved. At any rate it was too easy to bring forth accusations of deceit and fallacy against them. It was too evident that they showed figures in places where the corresponding objects did not exist (a first demonstration was given by the plane mirror, yet so simple and elementary); furthermore they showed enlarged what was small, small what was big, and at times would show upside-down what was straight, coloured what was colourless. It was inevitable that this should be considered an *alteration of reality*, or rather, deceit, falsehood, fallacy. Whoever examined the question from the viewpoint of the current theories, found that they agreed in considering optical systems unfavourable for vision. The theory of visual rays required, for the right functioning of the ocular system, that the visual rays emitted by the eyes should be absolutely rectilinear and not bent on their way by reflexions or refractions; the species theory required that these species, in order to carry correctly to the eye the shape and colours of the body from which they had departed, should not be distorted in the least along their path. In conclusion, one was not to look in mirrors or through lenses : to look through them meant to ask to be deceived.

It was for this reason that mankind, although it had at its disposal the simple microscope, did not utilize it for twenty centuries. It had in its hands a miraculous means for investigation and thought it deceitful!

It is very little known, but has been unquestionably demonstrated in the literature mentioned, that, after lenses had been applied for the correction of presbyopia towards the end of the thirteenth century, science unanimously would not take them into consideration and they remained for three whole centuries merely an artisan production. The first one to take the initiative to speak of lenses in a printed book was the Neapolitan Giambattista della Porta, and he treated of them because he wrote his well-known *Magia Naturalis*. That is to say, lenses entered into literature as 'magic'. This happened for the first time in 1589. The events that occurred the following year have been reconstructed in many of their details in the literature quoted. There was a rapid change of direction in optical questions; but the great merit of having shattered the bimillenary scepticism of philosophers and scientists against direct vision and observation through optical instruments was Galileo's. He was the first man of science who claimed that the 'telescope' was 'an instrument of inestimable usefulness', as he wrote in his letter of 24th August, 1609, to the Venetian Senate; this he proclaimed when the whole scientific world was still convinced, profoundly convinced, that it was 'a fallacy'.

And when Galileo, by means of the telescope, and only by means of the telescope, discovered the satellites of Jupiter and communicated it to the world in his marvellous book, *Sidereus Nuncius,* the whole world remained incredulous and accused Galileo of error, of ingenuity, if not actually of fraud. He affirmed his complete faith in the existence of the satellites of Jupiter, giving them the name of 'Medicean Planets', the name of his patrons, the Grand Dukes of Florence. This act is not to be thought an adulation but as a pledge, for Galileo was setting his whole future on the true existence of the Jupiter satellites, because if they had proved to be an illusion or a deception, as all scholars of the time insisted, to have given the name of the Medici to an illusion would have meant Galileo's civil death.

The furious controversy that followed, of colossal proportions, had all the characteristics of a great, decisive battle, in which all weapons were used to demonstrate the truth of classical theories and the fallacy of the telescope. The publication of Francesco Sizi's *Dianoja* represented the synthesis, the range of conservative forces. It is a marvellous book that recently has been restored to light and has been published translated from Latin into Italian. All the reasons, with which the sixteenth-century science concluded that one was not to look through the telescope, are related with extreme precision and faultless logic.

But events precipitated : the 10th September, 1610, Kepler, then the most competent person in optics of the whole scientific milieu, after a keen experimental critique such as would be made by one who wanted to reach the conclusion that the telescope was a fallacious instrument, had to admit that the telescope was not a fallacy and wrote Galileo the famous phrase of the dying Julian the Apostate : 'Vicisti, Galilaee !'

Galileo and the telescope had won their great battle.

Although since then the scientific mentality regarding both direct observation and observation through optical instruments was to undergo a deep change, this could not, however, take place within a few years. As it always happens when there are profound revolutions, the older people continue to believe what they have learnt in youth, and it is the young people who follow the road outlined by new ideas; that is to say : the assertion of these new ideas requires a few generations.

Therefore, microscopy started in the second half of the seventeenth century and not before; and in full harmony with this historical reconstruction is the fact that the father of microscopy was a young technician with an industrial and not a scientific background, and who had indeed a very modest education and held a very modest position, such as that of an 'usher', and was illiterate.

It was necessary that it should be a 'new man' lacking of culture and of prejudices in order to devote himself to microscopy with entire *faith* and with so much enthusiasm : such was van Leeuwenhoek.

The work of these pioneers changed the scientific mentality to such a point and, above all, their discoveries, besides the influence they had, have so modified the judgment about the value of observations carried out with optical instruments that today not only we blindly believe (it seems a pun) in what can be seen through these instruments, but we cannot believe that there could have been times in which people could have thought differently to the point of not seriously believing in what they saw. In fact no one has ever reconstructed antique and medieval history on these bases, as has been done in the quoted literature: however the documentation quoted in this literature is unquestionable.

We must add, to complete the historical picture summarized here, that at the same time in which Galileo was affirming his faith in observation through optical instruments and was able to infuse it into the whole sixteenth-century scientific milieu, Johann Kepler was bringing to a conclusion the great bimillenary effort to find the key of the mechanism of sight and gave the rules that still today are at the basis of the optical theory. This great discovery, published in 1604 in the book, *Ad Vitellionem Paralipomena*, allowed to confine 'optical illusions' to a modest role of negligible size and importance in the optical theory, instead of forming an outstanding part of it as it did during the antique and medieval period. This has contributed in a decisive manner to strengthen the 'faith' that now allows to look through telescopes and microscopes with hope of success.

Scientific progress and faith, through the work of two great men, Kepler and Galileo, have brought about the establishment of microscopy, though not they directly but an usher endowed with very modest culture has been the direct introducer of the new optical technique.

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