Descriptive catalogue of the collection of microscopes in charge of the Utrecht University Museum ; with an introductory historical survey of the resolving power of the microscope,

DESCRIPTIVE CATALOGUE

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Collection of Microscopes

in charge of the

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Historical Survey

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Resolving power of the Microscope

by

P. H. VAN CITTERT

1934
P. NOORDHOFF N.V. – GRONINGEN – (HOLLAND).

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PREFACE

This descriptive catalogue of the collection of microscopes in charge of the *Utrecht University Museum* differs in a few respects from most, if not all, catalogues of other collections. It is, in the first place, not concerned only with the design and the mechanical arrangement of the instruments, as is usually the case, but it also aims at giving, with constant reference to the Utrecht collection, a survey of the historical development of the magnification and the resolving powers as well. In the second place, it deals with the 19th century microscopes in more detail than is to be found in the greater number of such catalogues. The development during that period is, indeed, by no means less important and interesting than during the 18th century. In the 19th century, too, one meets with tentative efforts to arrive at the best form for the supporting stand and also with a variety of minor alterations, introduced as improvements, but subsequently withdrawn. Above all, however, the 19th century is remarkable for the development of the simple non-corrected objective into the modern one whose actual resolving power has practically reached its theoretical value.

This collection contains a few unique instruments of great historical interest. To begin with, there is the strongest of the remaining *"van Leeuwenhoek"* microscopes, further, the achromatic objective of *Beeldsnijder* made about 1791 and, finally, the two different types of the first achromatic microscope ever introduced on the market, both of them constructed by *van Deyl* about 1806. It contains, as well, the greater part of those instruments of which *Harting* published, in his well-known standard work, the magnifying and resolving powers as determined by him. For a long time *Harting* was a professor at Utrecht and director of the Zoological Laboratory, and not only the instruments belonging to that institute were at his disposal but also those belonging to the Physical Laboratory, which then, already, had become an important collection.

The Utrecht microscope collection itself is only a part of a very extensive collection of instruments (about 1200) owned by the University and in which three smaller collections are combined. First of all, namely, the instruments purchased since the year of its foundation (1706) by the Theatrum Physicum, secondly, those collected by the Physical Society (Natuurkundig Gezelschap) and thirdly, those brought together by the Utrecht University Museum. As regards the share of the Natuurkundig Gezelschap (which was founded in 1777 and still flourishes) we may remark that, especially during the first hundred years of its existence, it could dispose of ample means and started an exceedingly valuable collection of instruments which it ceded on certain conditions to the University in 1889. As regards the third contributor, the Utrecht University Museum, this includes among its activities the extension of the present collection. It is responsible for the description of the collection and also for the publication of this catalogue for which it gratefully acknowledges the financial support of the *Utrecht University Fund.*

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CHAPTER I

Some comments upon the development of the resolving power of the microscope.

The discovery of the lens includes the discovery of the microscope, for, once the first positive lens was constructed, its magnifying power must at once have been apparent. This means that the first microscope had thereby come into existence though most probably its magnification and resolving power were very poor. In course of time, however, it must have become obvious that the magnifying power of lenses increases with increasing curvature of their surfaces. Hence the tendency must have arisen to obtain ever stronger lenses by making them continually smaller. Since, however, the manipulation of such minute lenses became more and more inconvenient, it was only natural to mount them in some kind of lens-holder or supporting stem and to fit such a lens-holder or stem with an object-holder provided with a contrivance for the control of the focussing. This is how, what is commonly called, the simple microscope came into being, a type of instrument which held its own as long as until about 1830. And rightly so, for, however difficult the instrument may have been to handle, especially on account of the very small object distance necessary with higher magnifications, its optical qualities were unsurpassed then by any other type of instrument. The images are remarkably free from spherical and chromatic aberration, even with a magnification of 500 they give an impression of still being, practically speaking, perfectly achromatic. Indeed, as is clear from theoretical considerations, all aberrations from the ideal image, excepting the deviation from flatness, will in the case of strongly curved nearly spherical lenses only sligtly deteriorate the quality of the image.

From its origin down to the middle of the 19th. century the simple microscope has developed from a very primitive into a refined physical instrument. Whereas the earliest microscope consisted simply of a short tube fitted with a lens at one end and having the object attached to it at the other, the microscope constructed shortly after 1800 had a beautifully made supporting pillar, a convenient stage which often admitted of central adjustment and a perfect contrivance for focussing.

Though the closer study of the mechanical and constructional development of the microscope is very interesting, it is no doubt equally interesting to follow the development of the magnifying and resolving powers of these instruments during that same period. And the remarkable result is that from the earliest microscope in the Utrecht collection (and of the 17th century too), down to the middle of the 19th century hardly any improvement is found. The *van Leeuwenhoek* instrument, described under A. 1, proves to be one of the best microscopes as regards magnification and resolving powers made until the commencement of the 19th century. In order to make sure of this fact, all microscopes of the collection here described have been brought once more into a workable condition, all lenses have been cleaned as thoroughly as possible, and after these preliminaries the magnification and the resolving power of all instruments have been determined.

For the stronger simple microscopes as well as for the projection-microscopes the determination of the magnification was carried out by throwing the image of a reading scale, formed by the lens under investigation, on to a screen, at a fixed distance from the lens, and by measuring the length of the divisions. For the weaker simple microscopes and for the compound ones it was done with the aid of the camera lucida. All magnifications, those of the projection microscopes inclusive, are given for 25cm image distance.

As regards the determination of the resolving power, it was not possible to make use of the aperto-meter, as is usually done nowadays, because the numerical aperture gives the resolving power for those cases only in which both lenses and conditions for illumination are ideal. As soon as the lenses and the illumination are not ideal, the result of the aperto-meter method can only have the signification of an upper limit and the true resolving power corresponding to the actual state of affairs remains unknown. Even with the modern instruments of the best manufacture there is no absolute guarantee that the actual conditions agree sufficiently closely with the ideal ones to permit the application of the aperto-meter method.

When dealing, however, with instruments of the 17th and 18th centuries one may be sure that the actual conditions fall so far short of the ideal ones that this method can no longer be applied. It had therefore to be replaced by a direct one, now almost forgotten, but in common use about the middle of the 19th century. This direct method gives at once the true resolving power for the actual condition of the lenses and illumination during the measurements and ought therefore strictly speaking, to be preferred even for modern instruments to the first one. In the middle of the 19th century this method made use of a so-called *Nobert's test plate*, that is, a small glass plate in which a few groups of parallel equidistant lines are scratched, the mutual distances for each group being known. (cp. W. 5). Later on the "*Grayson Rulings*" 1) became more popular as a testing object. This is a thin realgar-film, also with a number of groups of parallel equidistant lines scratched on it (cp. W. 6). For the present determinations both the *Nobert plate* and the *Grayson Rulings* were used, mainly the latter, however, which in our case contained 12 groups of lines.

Numbering the groups in the order of their decreasing mutual line-distances, the latter amounts for group *a* to $^1/_{5000\,a}$ inch, which is equal to about $^1/_{200\,a}$ mm. If now, the examination of the plate in the microscope shows that group *a* is still resolved but the next group $a + 1$ not yet, the resolving power is sure to have a value between $^1/_{200a}$ mm and $^1/_{200\,(a\,+\,1)}$ mm.

For the small magnifications an object micrometer was used with divisions in $^1/_{100}$ mm. Our numerical results for the resolving powers are therefore given in $^1/_{100}$, $^1/_{200}$, $^1/_{400}$, $^1/_{600}$, ... mm. The source of light for this investigation was, except in the case of very high magnifications, an electric lamp at a distance of about one meter; the measurements are, therefore, the results of experiments with lightpencils of very slight divergence.

Let us now return to the simple microscope. It was clear from the measurements, that for the microscopes described below, one could fix, fairly sharply, the average magnification required to reach some definite resolving power. For instance, lenses with magnifications smaller than $\times$ 20 turned out not to be capable of resolving $^1/_{100}$ mm. For resolving powers between $^1/_{100}$ mm. and $^1/_{200}$ mm, the required magnifications had as a rule values between 20 and 40, etc. The results are collected in Table 1, and in fig. 1 the resolving power of the simple microscope is plotted against the magnification (continuous line).

Here, we are struck by the fact that the point *L* furnished by the oldest instrument of the collection, (the *van Leeuwenhoek* microscope) not only fits the curve perfectly, (a magnification of 270 resolves in this case $^1/_{700}$ mm. i.e. the 4th group of a *Nobert* plate) but that it even lies very high on the curve; it is only surpassed by a few 19th century microscopes fitted with doublets and by one, only one, small lens of Dollond dating from that same period, with a magnification of 480.

Considering that *van Leeuwenhoek's* instrument attains its prominent position in spite of a badly scratched lens it would in its

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1) These were introduced on the market by the firm *Beck* in London; they are nowadays, however, no longer made and have, practically speaking, disappeared from the market.

original condition have furnished a point lying much higher than the average.

As regards the projection-microscopes, one might, from theory, expect the same relation between magnification and resolving power as that of the simple microscopes, for the fact that one uses the lens (of short focal length) in the first case as a projecting lens instead of as a magnifying glass does not appreciably alter the object distance, and, therefore, neither the numerical aperture. In reality, however, the resolving power proved to be less than that of the simple microscopes;

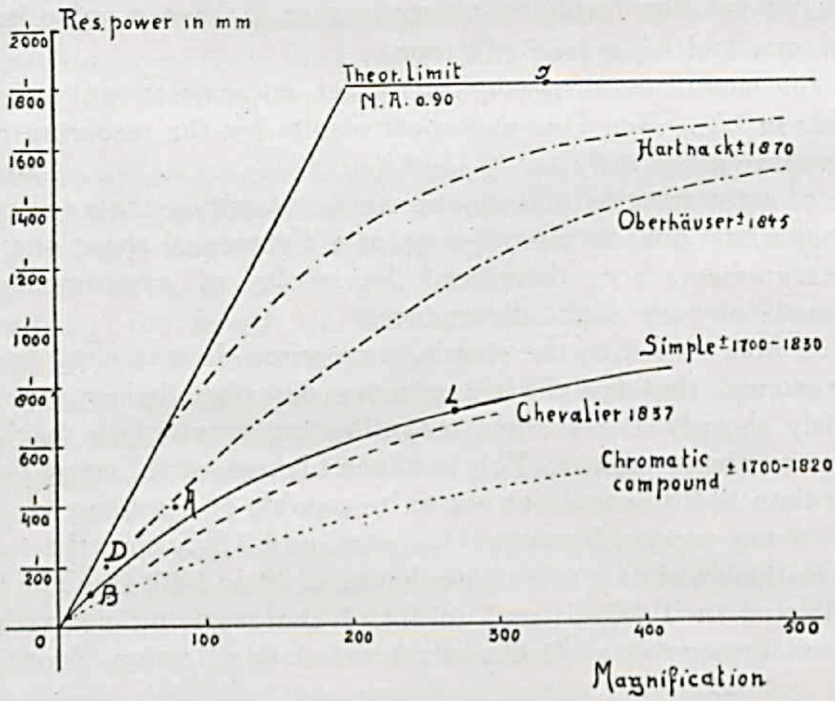

Fig. 1.

the obvious reason herefore is that the screen is never perfectly flat. The more it approaches ideal flatness the closer the resolving power will be to that of the simple microscope. In agreement herewith it was found experimentally that the resolving power is greater for projection distances of more than 25 cm. In order, however, to make a fair comparison with the simple microscope possible, the screen was held at the fixed distance of 25 cm from the lens. A sheet of white cardboard as smooth and as flat as possible, was used as a projection screen. The results are again given in Table 1.

We will now consider the development of the compound microscope as well. To all appearances, its more convenient manipulation

Tabel I.

Resolving power in mm.	Mean required magnification						
	Non-corrected microscopes			Corrected microscopes			Theoretical limit
	Simple ± 1700-1830	Projection ± 1740-1830	Compound ± 1720-1820	Chevalier 1837	Oberhäuser ± 1845	Hartnack ± 1870	
1/100	20	20	35	35	—	—	11
1/200	40	40	85	60	—	22[1]	22
1/400	100	120	250	120	75	45	44
1/600	200	—	—	220	115	70	67
1/800	360	—	—	—	165	100	89
1/1000	—	—	—	—	225	135	111
1/1200	—	—	—	—	295	175	133
1/1400	—	—	—	—	395	235	156
1/1600	—	—	—	—	—	360	178
1/1800	—	—	—	—	—	—	200

and the greater object distances, offered the observer many advantages. Here again, however, one meets with the same phenomenon as in the other types of microscopes. In the course of the 18th century namely, a considerable improvement in the mechanical construction was obtained, but hardly any progress was made as regards the optical capacities, and moreover, the optical powers of the compound microscopes turned out to fall short, by a long way, of those of the simple microscopes. This can be seen at once in Table 1 and from the dotted curve of fig. 1. A comparison, too, in the present catalogue of the optical data of the various instruments will at once reveal the fact that optical capacities of the compound microscopes have remained the same during the whole of the 18th century. The original *Culpeper* microscope, for instance, shows in this respect, hardly any difference from those instruments constructed about 1800. Even those improvements which were obviously necessary were neglected; the objectives, for example, are found to consist in the majority of cases of bi-convex lenses, if one comes across plano-convex lenses at all, they are almost invariably mounted with their convex surfaces turned towards the object and have evidently only been put in for the sake of their convenient mounting.

The reason why the magnifications of the compound microscopes are less than those of the other types is that the influence of the chromatic and spherical aberrations is much more predominant. The resolving power is less for the obvious reason, that a single lens, used as a simple microscope has a definite resolving power which can never increase, though its magnification can increase when the lens is subsequently combined with an eyepiece. If often occurs on the contrary that the resolving power of the combination is less than that of the single lens so that higher magnifications and lower resolving powers belong together.

Whereas the resolving power of the compound microscope remained, therefore, far below that of the simple microscope, so long as the objectives were not achromatized, this was no longer the case when once achromatic objectives were successfully made. The very first achromatic objective of *Beeldsnijder* (1791) is capable, when combined with a low power eye-piece, of resolving $^1/_{100}$ mm with a magnification of 20 (fig. 1 point *B*). With *van Deyl's* microscope (1806, M. 2) $^1/_{200}$ mm is already resolved with a magnification of 30 (fig. 1 point *D*). This proves that though as yet restricted to low magnifications only, the construction of the achromatic objective brought the compound microscope at once up to the level, or even above the level, of the simple microscope. It is worthy of note that in our opinion *van Deyl* owes his remarkable success not only to his achromatic objective, but also to the fact that he constructed his lenses in such a way that they partly neutralized their separate spherical aberrations. Both surfaces of all the lenses in his instrument have different curvatures and are mounted in such a way that the light-pencils that go to form the image pass through them at favorable angles.

Soon, however, the restriction to low magnification was felt as a serious drawback. The achromatic objective must necessarily consist of a convex crown lens and a concave flint lens. Now in order to obtain high magnifications the convex lens must be very much more powerful than in the case of a single nonachromatized lens and this leads to practical difficulties in their construction. *Selligue* and *Chevalier*, soon followed by others, were the first to obtain high magnifications by combining into a system a number of small lenses each of which had been achromatized separately as well as possible. The advantage of this method was that by simply adding or removing one or more of the lenses one could very easily alter the magnification. The drawback, however, was the accumulation of the separate spherical aberrations, which in the case of higher magnifications spoiled the resolving power. This explains why the resolving power of the compound microscope, though increased considerably by achromatizing, still remained below that of the simple microscope. This is clearly demonstrated by the instrument (O. 1) constructed in 1837 by *Chevalier*, one of the best builders of microscopes of his time. From Table 1 and fig. 1 the — — — line, one can see that *van Leeuwenhoek's* microscope, dated about 1700, is even superior to it!

It is due to the genius of *Amici* that these difficulties were overcome. He showed that, in order to arrive at a high resolving power, the objective must be composed of different parts each of which separately still gives rise to aberrations, but which are so computed, that they neutralize each others impairing influence. He was also the first to draw attention to the part played by the cover-glass and to point out the great advantage of having at one's disposal a number of eyepieces of different powers, as well as a number of different objectives. He pointed out, moreover, the influence of a larger aperture and the important advantage of immersion. The microscope of *Amici* (1836) in the Utrecht collection turns out indeed to possess a resolving power far exceeding that of the simple microscope; with a magnification of 80 it resolves already $^1/_{400}$ mm (fig. 1 point *A*). When his method of constructing objectives was once generally accepted and followed, and the resolving power of the compound microscope went up by leaps and bounds, the cause of the simple microscope was lost! The microscope of *Oberhäuser* (about 1845, see Q. 2) or better still that of *Hartnack* (about 1870, see Q. 3) makes this clear to us in a most convincing way. (See Table 1 and fig. 1 the — — . . line, resp. the —.— line). The line referring to the *Hartnack* microscope moreover shows, that, in the case of lower magnifications, this instrument has already reached the theoretical limit, represented in fig. 1 by two continuous straight lines. The horizontal line gives the theoretical limit for NA = 0.9 and λ = 5000 Å The construction of the slanting line is based on the experimental fact that the angular distance of two points must be at least 1½′ in order to be seen separately. And the achievement of a water-immersion, belonging to the same *Hartnack* instrument and which, with a magnification of 340 is able to resolve $^1/_{1800}$ mm is also represented in fig. 1 (point *I*). It is clear from this that at about 1870 the resolving power of the compound microscope had already attained a very high value. It is, indeed, very interesting and instructive, that an entirely new microscope constructed in one of the most famous factories in the world yielded exactly the same curve for its resolving power as the *Hartnack* instrument which was made about 65 years previously!

We may summarize these comments on the resolving power of the microscope as follows: From 1700 to 1800 only the construction and the mechanical arrangement of the simple and of the compound microscope were improved. The optical capacities however, show hardly any improvement.

The simple microscope is, during this period, far superior in optical respect to the compound one, which explains why scientific observers invariably fall back on the former type of instrument for their most important investigations. The successful construction and the development of the achromatic objective opens a period of increasing resolving power of the compound microscope. At about 1830 the compound microscope definitely outdid the simple microscope, which from this time onwards loses its leading position and is nowadays only used as a dissecting microscope or as a magnifying glass.

In this connection we may perhaps once more draw attention to the remarkable fact that, as regards optical powers, the *van Leeuwenhoek* microscope (A. 1) must have been one of the best microscopes ever made before 1830. It is therefore no wonder that *van Leeuwenhoek*, possessing all the qualities of a keen observer was able to make *such* startling discoveries with this instrument, that up to the present day the scientific world is still amazed by them. Nor is it to be wondered at, that their reliability and correctness were formerly often doubted, for the simple reason that they could not be repeated.

CHAPTER II.

Simple Microscopes.

A. Van Leeuwenhoek microscopes .

Anthonie van Leeuwenhoek (1637—1723) was undoubtedly the pioneer of those sciences dependent on the microscope for their data. For, at a time when, as yet, only the rudiments of the simple, as well as of the compound, microscope existed and therefore only the most primitive instruments were at his disposal, he succeeded in making extremely interesting discoveries. The reliability, however of his observations was often doubted, then and later, simply because no one was ever capable of repeating them. It was considered next to impossible that with such a poor outfit — a very small lens, which he had ground and polished himself, let in between two roughly finished brass plates, and some rough arrangement for focussing — he should have succeeded in observing protozoa, bacteria, cilia, etc. Even nowadays the scientific world is still amazed at his having obtained such important results with such simple means. And again and again one meets with the opinion that *van Leeuwenhoek* must have had better means at his disposal as well. Quite recently, even, the same view has been put forward in this matter and it has been suggested that *van Leeuwenhoek* must have been acquainted with "dark ground illumination". [1])

It is, of course, very probable that this phenomenon was actually observed by him, as the present writer is quite willing to admit but it is not at all necessary to assume that *van Leeuwenhoek* must, purposely, have made use of it for his observations. Measurements of the optical powers of the small microscope, described under A. 1. show that this instrument even in its present condition, with the lens badly scratched on the side of the object, is capable of resolving, with a magnification of 270 the line structure of a grating of which the spacing is $^1/_{700}$ mm; one may safely assume that, when in good condition in *van Leeuwenhoek's* time, its resolving power must have been considerably higher. This means that this little instrument must have surpassed in optical capacities any of the compound microscopes of the 18th century and that not until the beginning of the 19th century, some, though not many, instruments of more efficiency are to be found. Besides, it is not quite certain that the microscope in this collection is the best of all he ever made. It is only

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[1]) Cp. *C. Dobell: „Antony van Leeuwenhoek and his little animals"*, pg. 332.

the strongest among those still left of the 250 microscopes made by him, which existed at the time of his death.

Van Leeuwenhoek possessed all the qualities that go to make a first-rate observer: keen eyesight, ingenuity and discrimination and, undeniably, an indefatigable patience without which he could never have worked with such clumsy apparatus at all. Moreover, his skill in grinding and polishing lenses must have been exceptional. And yet even all these excellent qualities do not explain his outstanding

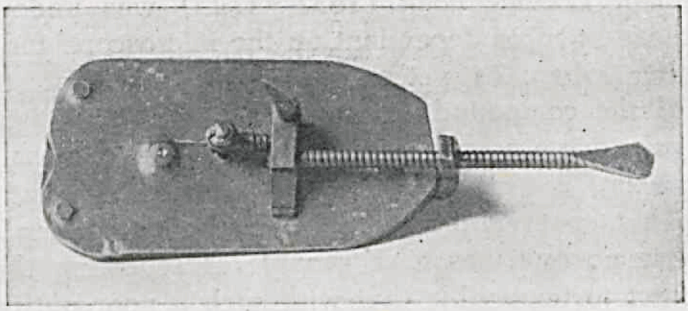

Fig. 2.

success. This can be only fully understood by taking into account the fact that he used exactly the type of microscope, which by its high resolving power made his discoveries possible.

If, at that time, the compound microscope had already offered the misleading advantages of a much more convenient manipulation and its apparent superiority over the simple microscope, instead of being still at the beginning of its development, and if *van Leeuwenhoek* should thereby have been induced to prefer the former type to the latter he would never have obtained his startling results. In short, he made his discoveries not in spite of, but thanks to, the fact he made use of a primitive simple microscope.

A. 1. Microscope of "van Leeuwenhoek".

This small instrument consists of two very badly finished brass plates rivetted together and measuring about 4.5×2.5 cm^2 (fig. 2). Between them a very small lens is fitted, having an effective diameter of 0.5 mm. For examination, the object is stuck on a small point. This point can be removed, which suggests that, originally, the instrument was occasionally used with object-holders of a different shape. What kind of object-holders these may have been is not known. For focussing, the distance between the point and the lens can be varied by a screw. This screw is 1 cm long; it has only 11 windings in all and of very bad workmanship at that! Since moreover, the focal length of the lens is very small, it is clear that the actual focussing is an extremely tedious affair!

In order to make the successive examination of different parts of the object possible, the brass piece which carries the object-point is attached to a long screw running parallel to the plates. The female screw is in the shorter arm of a brass angle-piece, of which the longer arm can turn round another screw, by which it is attached to the brass plates. By this arrangement the object can be made to move in all directions. A coarsely finished leather case belongs to this instrument.

As regards the lens, it is bi-convex, the radii of curvature are ± 0.75 mm; its greatest thickness ± 1.1 mm. (fig. 3). The brass plates between which it is fitted serve at the same time as diaphragms; the aperture on the object-side is 0.5 mm, on the other side 0.8 mm. The distance object-lens is about 0,5 mm. For the numerical aperture a value of about 0,4 was found. The theoretical resolving power is 1 μ, but in practice, details not less than $^1/_{700}$ mm apart, are still seperated. The magnifying power of the lens is × 275.

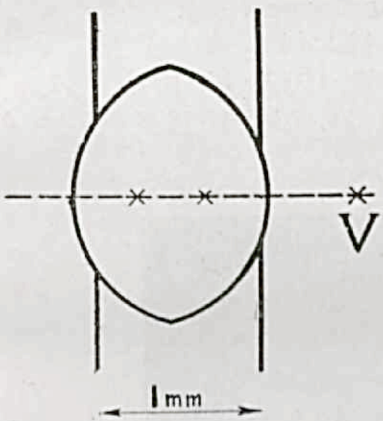

Fig. 3.

The fact that on the object-side the lens is more or less badly

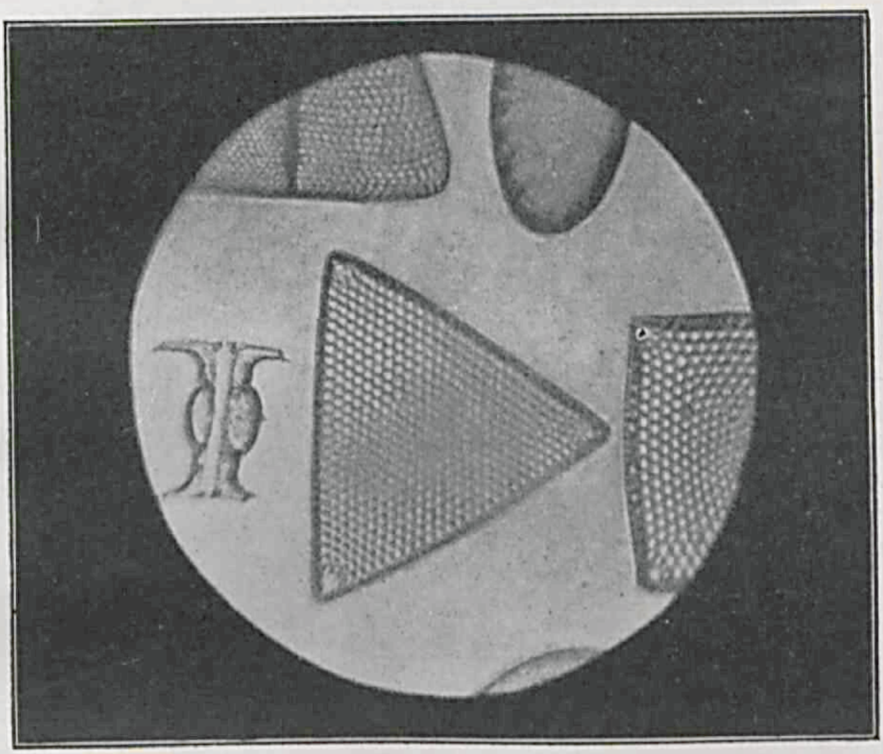

Fig. 4.

scratched rather spoils the image, which therefore is doubtlessly less satisfactory now than when *van Leeuwenhoek* himself used the instrument. Yet structural details, the size which is somewhat more than 1 μ, are still resolved; coloured bacteria of a size between 1 and 2 μ can be seen clearly, and living bacteria measuring about 5 μ are easily observable.

Fig. 4 shows a microphotograph of a few diatoms. The magnification used in this instance was × 200; the actual length of the side of the triangle in the figure is 0,18 mm.

For a very complete description of our instrument see:

P. Harting, Het microscoop III, pg 43—44.
P. H. van Cittert, Proc. Amst. 35, 1062, 1932; *36*, 194, 1933.
P. H. van Cittert, Natuur en Mensch, *53*, 136, 1933.

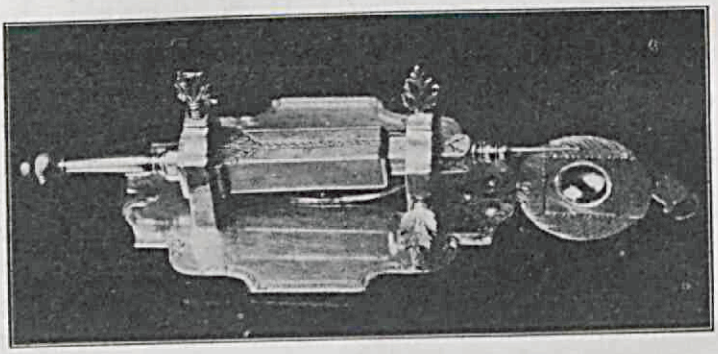

Fig. 5.

A. 2 A copy of the van Leeuwenhoek microscope.

The workmanship of this instrument (fig. 5) is much better than that of the original one. The construction of the objectholder is altogether more solid and better finished. Its motion too can be better controlled. The size of the instrument is $5\frac{1}{2} \times 15$ cm^2.

Originally, the lenses belonging to it were interchangeable one with another. At present, however, there is only one lens left having a magnifying and a resolving-power of × 30 and $^1/_{100}$ mm respectively.

The microscope is not signed. To judge from its decorative designs, however, which remind one strongly of *Joblot*, its construction, very probably, dates at about 1700.

B. Simple magnifying-glasses provided with object-holders.

B. 1. The "van Musschenbroek" microscope. [1])

The authenticity of this instrument is testified by the trade-mark of the *van Musschenbroek's* viz. "the oriental lamp" and by the arms of Leyden. It is, in fact, more like an ordinary magnifying glass to which a movable object-holder is attached, than like a real microscope (fig. 6). The various lenses, all of which have wooden mounts,

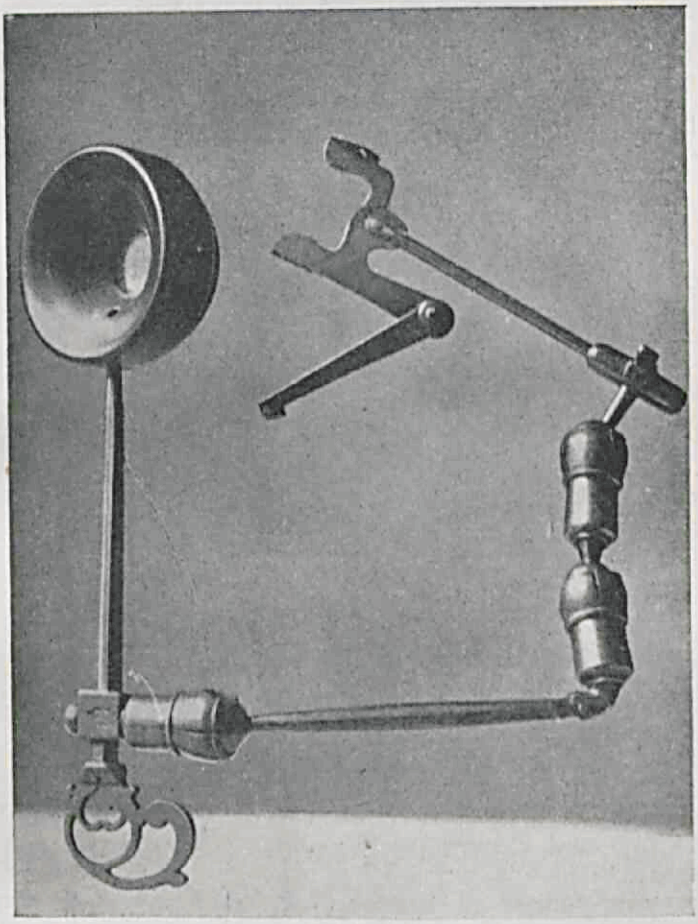

Fig. 6.

[1]) *Johan van Musschenbroek* (1660—1707), who made this instrument, and his brother *Samuel Joosten van Musschenbroek* were instrument-makers at Leyden.

can be pushed so as to fit tightly on a brass spike. The object-holder is attached to the lower end of the spike by means of three ball and socket joints which allow of the displacement of the object in all directions.

The object-holders at present accompanying the instrument are a wooden disc and a brass mount for holding capillary-tubes.

To the instrument belong, further, three lenses with respective

Fig. 7.

magnifying-powers × 8, 15 and 30. The last one resolves $^1/_{100}$ mm.

This type of microscope is a.o. described, (resp. illustrated) in:

Ledermüller II, pg 56 resp. Tab XXXII.
Harting III, pg 48 resp. pl. I, fig. 10.
Petri, pg 44—45.
Clay and Court, pg 37—38.

Both of them were famous as designers and constructors of microscopes and vacuum-pumps. Johan's sons, *Jan* and *Petrus van Musschenbroek* were both famous too. The former as an instrumentmaker at Leyden and as *'s-Gravesande's* collaborator, the latter as a professor of Physics in various universities, including Utrecht and Leyden. (cf. C. A. Crommelin. Physics and the Art of Instrumentmaking at Leyden in the 17th and 18th centuries.)

B. 2. Small microscope on wooden foot.

This instrument (fig. 7) is remarkable for its object-holder, which consists simply of a wire spring. For focussing, this spring is pressed by hand toward the stem. The power of the lens is × 15. A cardboardtube serves as a case for this very primitive instrument.

Part of it is illustrated in 's-Gravesande's Elemens de Physique. Leyden, 1745, II Tab. CIII fig. 1.

It is also described resp. illustrated in a slightly different execution (with springless object-holder) in:

Ledermüller II, pg 55 resp. Tab. XXI.
Harting III, pg 40 resp. pl. I fig. 2.
Petri, pg 40. 41.

C. The screw-barrel microscope of Hartsoeker-Wilson.

This type of microscope was constructed in 1694 by *Hartsoeker.* [1]) In 1702 after it had been slightly altered, *Wilson* introduced it successfully and made it more popular. Its chief feature is its very compact build. It consists of a short brass tube which can be attached either to a handle or to a fixed stand. The small lens, mounted, either in wood, brass or ivory is screwed in at one end of the tube. The object is mounted in glass or between two small plates of mica which are fastened together in ivory or horn. For examination it is pushed between two brass plates which can be slid along two grooves of the tube. The position of these two plates relative to the lens can be varied by turning a second brass tube screwed in at the other end of the first tube. This second tube sometimes contains a condenser.

In order to examine an opaque object this is stuck outside the instrument on a sharp point or in a forceps clamped between the two plates. The lens is then brought in the right position over the object by means of a lens holder made especially for this purpose. For a description, resp. illustr. of the screw-barrel microscope see, among others:

Baker, pg 8—15 resp. pl. I and II.
Ledermüller II, pg 10—14 resp. Tab. V and VI.
Adams, pg 115—118 resp. pl. II B.
Harting III, pg 59 resp. pl. I, fig. 4, 17 and 18.
Petri, pg 55 and 60.
Clay and Court, pg 43—57.

C. 1. Small microscope on handle, after Hartsoeker-Wilson.

This instrument is signed: *"G. Cramer, Groningen. fecit"* [1])

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[1]) *Nicolaas Hartsoeker* was born at Gouda in 1654. He settled as a maker of microscopes in Rotterdam but in 1684 moved from there to Paris where he lived for twelve years and became very well-known for his capacities as a grinder of lenses and as a physicist. In 1697 he was appointed teacher of physics to Czaar Peter the Great, and on this account the town of Amsterdam put a small laboratory at his disposal. Later on he was appointed professor in Heidelberg and finally settled down in Utrecht where he died in 1725.

[2]) *Gerrit Craamer* or *Cramer* lived from 1738 till his death in 1755 at Groningen. No further particulars concerning his profession are to be found in the archives.

The accessories belonging to it are four strong lenses provided with ivory protection-caps and two weaker lenses, object-holders for the examination of opaque bodies and a small tube containing various objects. All these things are kept in a shagreen leather case.

Accompanying the microscope is a list written by hand giving the various focal length's and magnifying powers of the lenses and also an inventory of the objects. The respective magnifying powers and resolving powers of the various lenses are:

Lens	Magn. p.	Res. p.
1	× 400	$^1/_{600}$ mm
2	160	$^1/_{400}$ " "
3	100	$^1/_{400}$ " "
4	57	$^1/_{200}$ " "
5	26	$^1/_{100}$ " "
6	16	$^1/_{100}$ " "

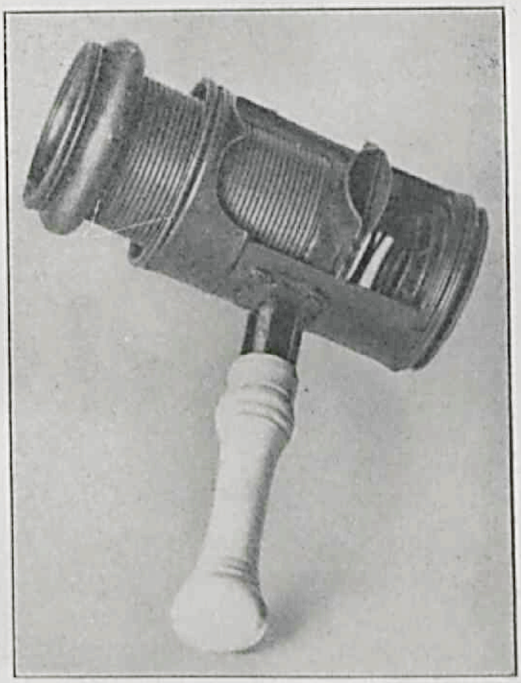

Fig. 8.

C. 2. Small microscope on handle after Hartsoeker-Wilson.

This instrument (fig. 8) is signed *"Culpeper fecit"*. Of all the accessories which belonged to it only one lens is left. Its magnifying power is × 18 and its resolving power $^1/_{100}$ mm.

C. 3. Microscope after Hartsoeker-Wilson.

The microscope is attached to a stand which is fixed on a mahogany box. Accompanying it are three lenses with powers × 15, 25 and 40. The two latter resolve $^{1}/_{100}$ mm.

This instrument is signed "*C. van Wijk fecit*" *Utrecht 1783* [1]). It was presented by the Foundation of Renswoude, (together with other instruments, some of which also made by van Wijk) to the Museum of the University of Utrecht.

C. 4. Microscope after Hartsoeker-Wilson.

This instrument has a stand fixed on a small wooden box (fig. 9). It is signed "*Jacobus Lommers fecit. Utrecht 1760*" [2]). Two lens-

Fig. 9.

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1) *C. van Wijk* was a ward of the van Renswoude Foundation at Utrecht, which had him trained as instrument-maker, first at Utrecht, and later on in Paris. Subsequently he became instrument-maker to Teyler's Foundation at Haarlem.

2) *Jacobus Lommers* came as a soldier to Utrecht, about 1715, where he

holders belonging to it are still left, but only one of them is fitted with a lens. Both holders are threaded so as to make it possible to screw a short tube with an eye-piece on to the holder. By this device the simple microscope could easily be altered into a compound one. This extra eye-piece tube is now missing. In the catalogue, dated 1839, of instruments belonging to the Physical Laboratory our instrument is described as a compound one and Harting also mentions the said tube in his book. (Harting III pg. 144).

C. 5. *Microscope after Hartsoeker—Wilson.*

This microscope, which can be used either attached to a handle or fixed on its wooden box bears the signature *"J. G. Brinkman fecit Bremen"*. Accompanying it is the complete set of accessories, viz. lens- and object-holders for opaque objects and 5 lenses. The respective magnifying and resolving-powers of the lenses are:

Lens	Magn. p.	Res. p.
1	× 120	1/400 mm
2	80	1/200 „ „
3	50	1/200 „ „
4	40	1/200 „ „
5	25	1/100 „ „

C. 6. *Microscope (altered) after Hartsoeker-Wilson.*

This small instrument can, like the one described under C. 5, be used in two ways, either attached to a handle or screwed on to a stand fixed on a small wooden box. The illuminating mirror is missing. The focussing differs from that of the ordinary type and is here effected by moving the lens relative to the object by means of a screw. The accessories accompanying it are:

the object-holder which is a double one, comprising

1) the usual Wilson object-holder and
2) a small brass box with glass top and bottom for the examination of liquids and living objects,

and 3 lenses with powers × 12, 25 and 40, of which the last one resolves 1/100 mm.

married in 1717. In 1743 the astronomical instruments of the University of Utrecht were placed in his charge. In 1747 he appears to have established himself as an instrument maker. On account of his high capacities in this line he was offered the citizen-ship of Utrecht free of cost. He was, very likely, connected with the „Theatrum Physicum" of the University of Utrecht. Various instruments made by him are now in the collection of the Utrecht University Museum. (Cp. G. A. Evers, Maandblad van „Oud Utrecht" 3, 27, 1928).

D. The simple microscope after Cuff.

About the year 1750 the Englishman *Cuff* began to construct microscopes of a different design. Its advantage over the screw-barrel model was the more convenient way in which the object could be handled. This accounts for its holding its own for such a long time as a standard model for the construction of microscopes. Even the dissecting microscopes of today are still built on these lines.

The main feature of this instrument is the fixed object-stage which is attached to the supporting-pillar. The latter may or may not be fixed to the box of the microscope. Underneath the object-stage is the illuminating-mirror and above it the lens. The lens is adjustable with respect to the stage in various ways either by simple moving it up and down by hand, or by means of a screw, or by rack-and-pinion motion.

In the 18th century two types of instruments were distinguished, viz. the "aquatic" and the "botanic" microscope. In the first type the lens was capable, apart from its up and down motion, of a motion sideways, parallel to the plane of the stage. This made it possible to search a drop of water for protozoa and suchlike objects. The "botanic" lens could only move up and down. A description of a probably genuine Cuff microscope is given under H.1.

For description, resp. illustration of the original Cuff microscopes the reader is referred to:

Harting III, pg. 67 resp. pl. II fig. 21.
Petri, pg. 63—65.
Clay and Court, pg. 66—69.

D. 1. Microscope after Cuff.

This instrument, which is not signed, was made by *Jacob Huisen* [1]) for the Theatrum Physicum of the Utrecht University and delivered on October 2nd 1758 as is shown by the books (accounts) of the

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1) *Jacob Huisen* was born at Stralen. From 1739 until the time of his death 1792 he was an instrument-maker at Utrecht. In 1750 he obtained the citizenship of Utrecht free of cost on account of his great merits in his profession. His son *Hendrik Huisen* was later on connected with the Theatrum Physicum of the University of Utrecht. A few more instruments belonging to the university collection are also made by this *Jacob Huisen*.

town where the sum of *f* 128.17.— is entered on that date in payment of it.

The focussing is effected by a rack-and-pinion motion. The rack itself is pressed into the stand by means of spring (fig. 10). Among

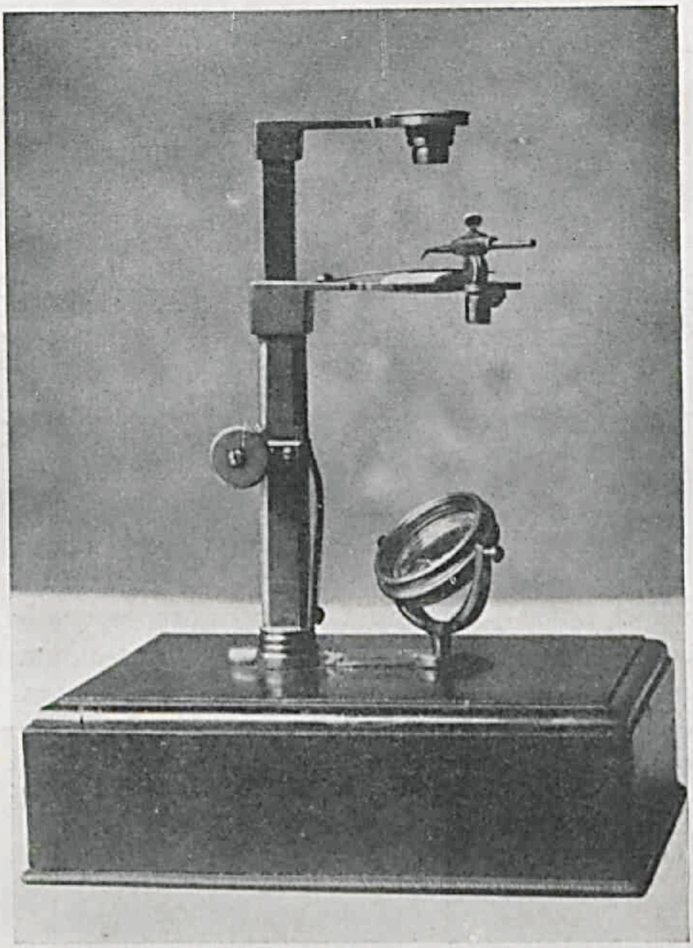

Fig. 10.

the accessories accompanying the instrument are 10 lenses of various powers, one of them is very strong, two others are fitted with a hollow metallic mirror for illuminating opaque objects from above, (the so-called Lieberkuehn mirror). Only 5 of the lenses are in a satisfactory condition. Their magnifying and resolving powers are as follows:

Magn. p.	Res. p.
× 16	—
20	$^1/_{100}$ mm
30	$^1/_{100}$ „ „
40	$^1/_{200}$ „ „
60	$^1/_{200}$ „ „

D. 2. Microscope after Cuff.

This microscope is similar in every respect to the one described under D. 1. The 8 lenses belonging to it, have the following magnifying and resolving powers.

Magn. p.	Res. p.
× 50	$^1/_{200}$ mm
32	$^1/_{200}$ „ „
28	$^1/_{200}$ „ „
21	$^1/_{100}$ „ „
20	$^1/_{100}$ „ „
19	$^1/_{100}$ „ „
10	—
8	—

D. 3. Microscope after Cuff.

This microscope is supported by a folding tripod which suggests a probable construction at about 1800. The stand is connected to the foot by a compass-joint and can therefore be made to incline. The focussing is effected by means of a rack-and-pinion motion.

Accompanying the instrument is a simple lens, (magn. p. × 15), which, however did not originally belong to it as is evident from the fact of its being threaded.

All of it is preserved in a small wooden box.

D. 4. Doublet microscope of Chevalier.

This instrument bears the inscription

"Charles Chevalier"
"Ingenieur Opticien"
"Palais Royal 163. Paris".

In 1835 the „Natuurkundig Gezelschap" (Physical Society) at Utrecht bought it for *f* 81.50. Its general build is mostly on the same lines as Cuff's original model (fig. 11). It was designed by *Chevalier* and an article about it was published in the *Ann. d. Sc. Nat. 1833.* A copy of this article belongs to our instrument. The focussing is done by an up or down rack-and-pinion motion of the lens-holder. Under the stage a cone carrying a rotating diaphragm with 6 apertures is attached to a folding hinge.

From the accessories belonging to the instrument two doublets are left, viz. No. 3 of which the magnifying and resolving power are × 45 and $^1/_{200}$ mm. and No. 5 with the values × 320 and $^1/_{600}$ mm respectively.

These same doublets were examined by Harting. As regards the magnications he obtained the same results. The resolving powers however which he found were $^1/_{450}$ mm resp. $^1/_{950}$ mm, from which it is clear that these powers have greatly diminished [1]) (Cp. Harting III p. 273).

For a description (resp. illustration) the reader is referred to
Harting III page 103, resp. pl. III fig. 1.

For further data concerning Chevalier's doublets see:

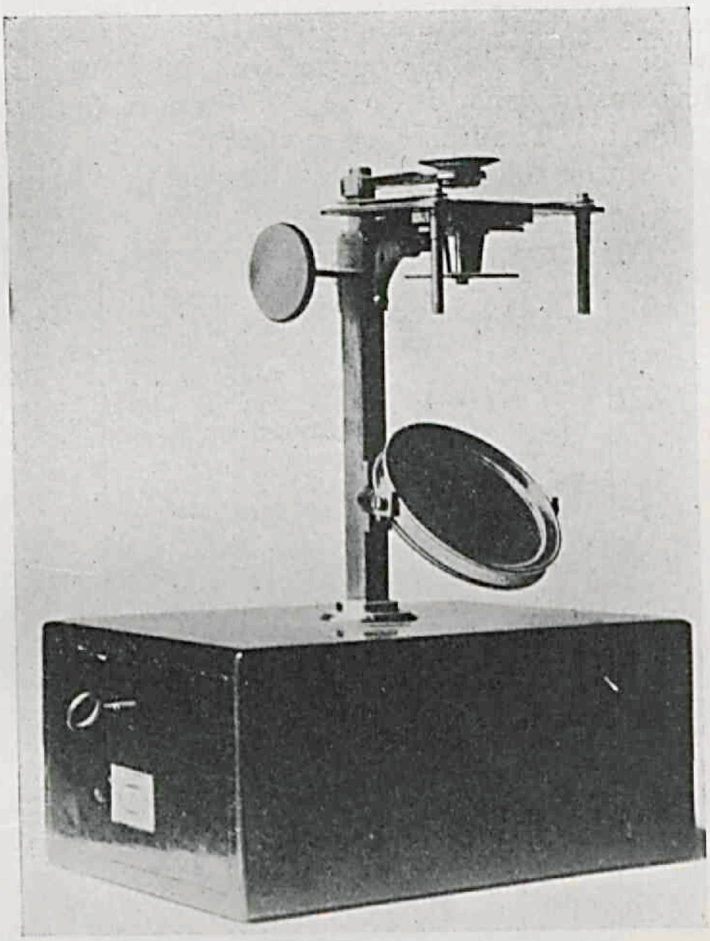

Fig. 11.

Harting III, page 80 resp. pl. II.
Petri, page 72.
Clay and Court, page 75.

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1) The space between the lenses of doublet No. 5 was full of verdigris and the lenses themselves have been obviously impaired by it too.

D. 5. Single microscope.

This microscope shows some strong deviations from the original Cuff type. In a flat rectangular hollow pillar, fixed on a round foot, a brass plate can be screwed up and down. The lens holder is attached to the top of this plate (fig. 12). There is only one lens left with a power × 15. This instrument was presented to the University Museum by the Foundation of Renswoude and was probably the work of one of the wards of that foundation.

D. 6. Pocket microscope of Robert Brown.

This instrument bears the signature *"Dollond London"*. It was bought by the Physical Laboratory for *f* 100 early in the 19th. century. Its construction differs greatly from that of the ordinary Cuff type (fig. 13). The lenses are mounted between two small brass plates which can be slid on the main pillar and can then be screwed

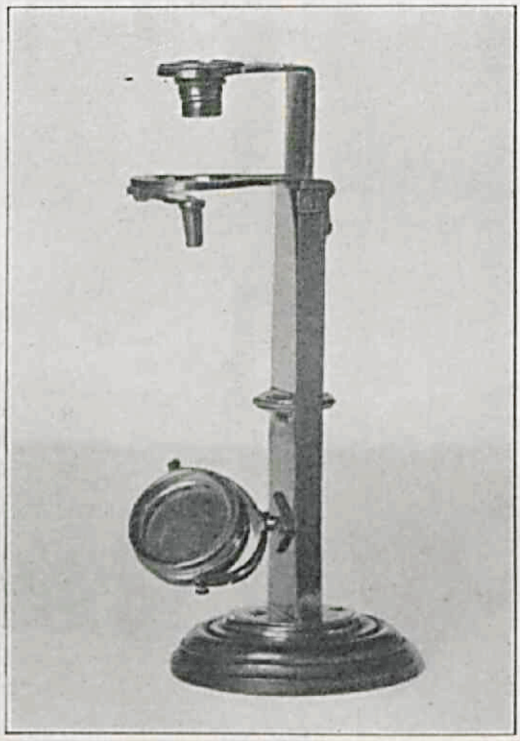

Fig. 12.

up and down with respect to the stage. The stage itself can be centrally adjusted. This is all contained in a small red morocco leather case. Among the accessories of this instrument are four lens holders, only three of which, however, are still fitted with a lens. Their magnifying powers and resolving power are respectively × 185 and

$^1/_{600}$ mm; × 330 and $^1/_{800}$ mm and × 480 and $^1/_{800}$ mm. Harting gives for the missing lens a magnifying power × 77.

A cursory mention of the instrument is made by Harting in III page 81, where he gives the powers of the lenses and comments upon

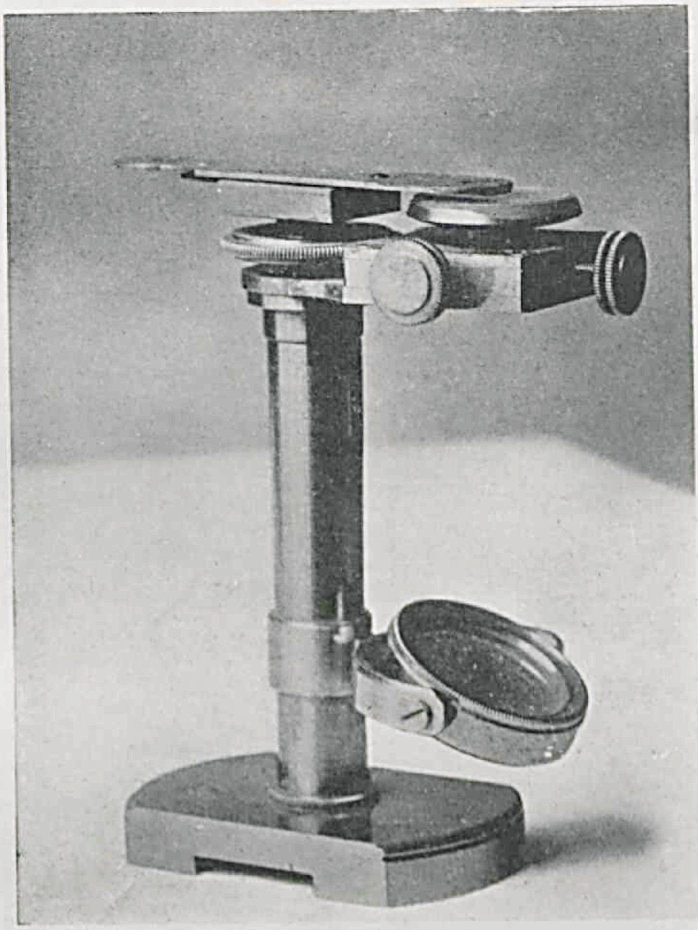

Fig. 13.

the × 480 lens as being the strongest lens obtained by grinding and polishing he had ever seen.

D. 7. Dissecting microscope.

As regards its general shape this resembles the Zeiss microscope, described and illustrated in Petri (pg. 95—96). The only difference is a wooden foot instead of a brass one. To the instrument belongs a case containing two doublet lenses of the Chevalier type with magnifying powers × 30 and × 60. Both of them resolve $^1/_{200}$ mm.

E. Doublet microscope of Wollaston.

About 1829 *Wollaston* started to construct doublets, consisting of

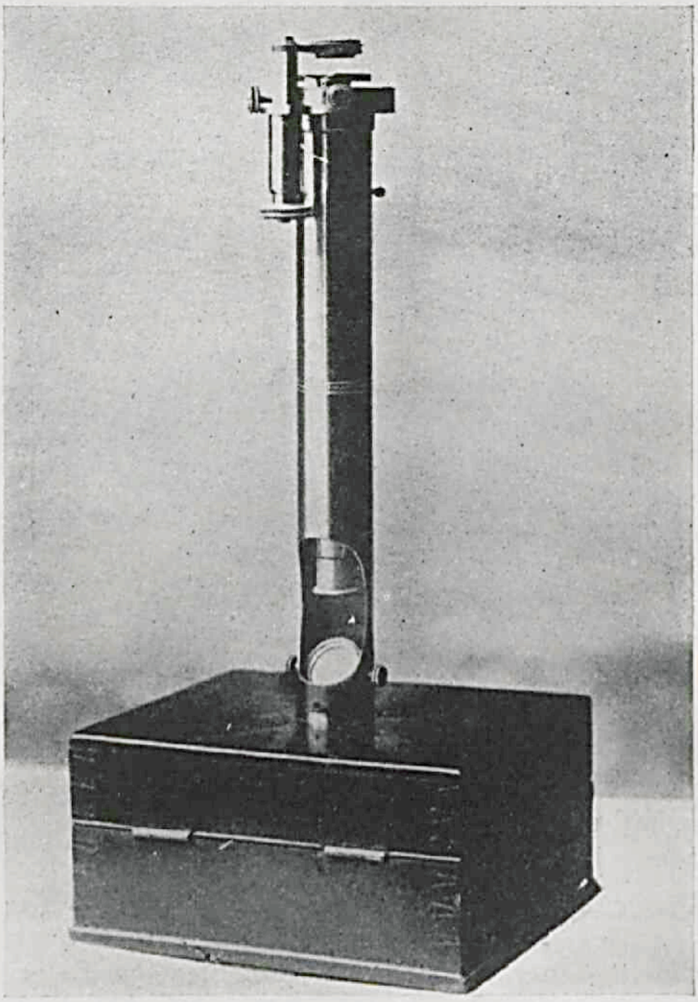

Fig. 14.

two plano-convex lenses, the focal length of which are in the ratio 3 : 1. The lenses are placed a short distance apart one above the other and have their plane surfaces turned towards the object. (Cp. Harting III pg. 77 resp. pl. II, fig. 9).

Wollaston designed and constructed a single microscope as well, which he fitted with a peculiar illuminating apparatus. A brass tube screwed on to a wooden box contained a fixed illuminating lens which concentrated the light from the mirror at the lower end of the tube on the object. Later on, Dollond made similar instruments but with an adjustable illuminating lens and an object stage capable of central adjustment.

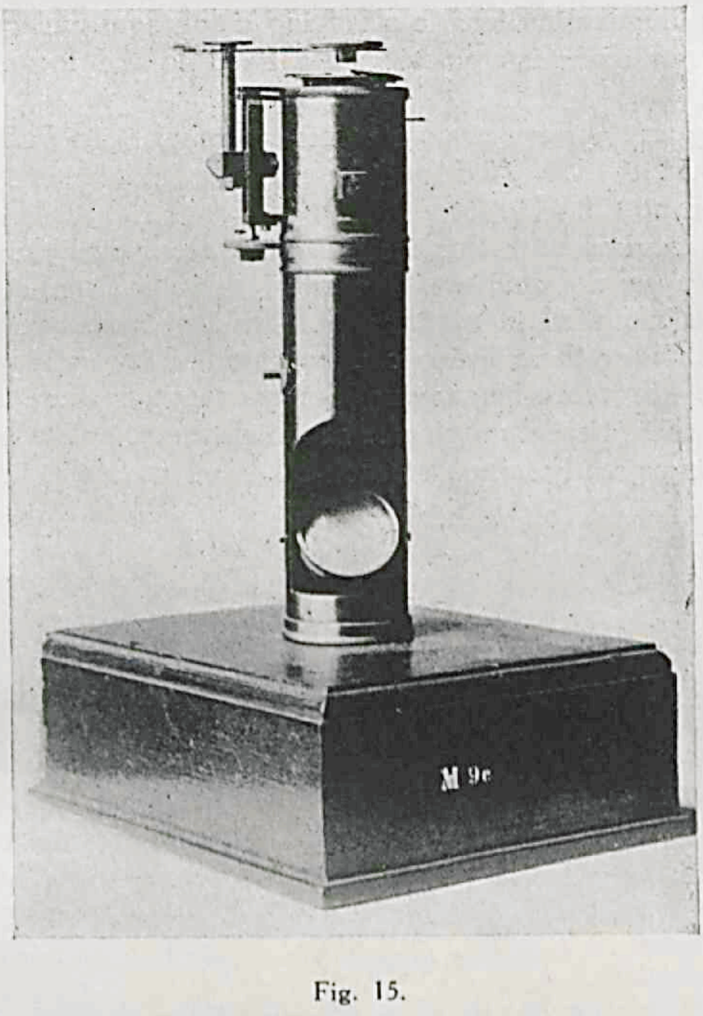

Fig. 15.

E. 1. Doublet microscope after Wollaston.

This instrument, signed *"Dollond London"*, was bought by the Utrecht *"Physical Society"* in 1835 for the sum of *f* 120. It is fitted with the illuminating apparatus mentioned above and with a centrally adjustable stage. (Fig. 14). Accompanying the microscope there are two doublets with magnifications $\times$ 200 and $\times$ 300, and with resolving powers $^1/_{400}$ mm and $^1/_{800}$ mm respectively.

For description resp. illustration see:
Harting III, pg. 77—78, resp. pl. II, fig. 10 and 11.
Petri, pg. 218.

E. 2. Doublet microscope after Wollaston.

This instrument was made according to special indications given by *Harting*. The characteristic features in which it differs from the original Wollaston construction are a larger illuminating mirror, an adjustable illuminating lens, a revolving diaphragm under the object-stage and an ivory micrometer scale fixed to the focussing screw. (Fig. 15).

Harting gave a very complete description of it in *Bulletin de Sc. phys. et nat. 1, 354, 1839* and a less detailed one in Harting III footnote on pg. 78—79.

Harting worked with this instrument a great deal though he did not actually use the doublets. Instead of these he fitted it with small glass beads mounted in platinum foil. In his book he describes at some length how these beads can be obtained by melting (Harting III pg. 58—59). Accompanying the microscope there are still a number of these beads, only some of which are complete with mount, and differing greatly, amongst each other, in strength.

F. Mounted magnifying glasses without object-holders.

F. 1. Thread counter or linen microscope.

This small instrument consists of a short wooden tube in which a lens, mounted in wood, can be screwed up and down. In the base of the tube is a small square opening, the sides of which measure exactly two "Rijnlandsche lijnen". This instrument was made for counting the number of threads contained in two "Rhineland lines". Its magnification is $\times$ 8.

F. 2. Economyglas in a red cover.

This is simply a short glass tube in which a lens (power $\times$ 4) can be screwed up and down. It was made for the purpose of examining living insects.

Cf. Ledermüller I, pg. 36 resp. Tab. LXX.
Petri, pg. 43.

F. 3. Stanhope lens.

This is a bi-convex lens mounted in silver. The plane of the object coincides with the surface of the lesser curvature. The lens is therefore always focussed on its own less-curved end so that for examination the object must be placed right up against this end. Its power is $\times$ 35.

For description and figure see among others:

Harting III, pg. 71 resp. pl. II, fig. 5.
Petri, pg. 68.

F. 4 and F. 5. Two Coddington lenses.

With a view to reducing the spherical aberration, *Coddington* devised the grinding of a groove round a glass sphere. By this contrivance only those rays which have passed through the lens near its centre can contribute to the formation of the image. The lenses were mounted on short brass tubes in which they were kept when not in use. (Fig. 16).

Both samples are made by *Cary*. Early in the 19th century the Utrecht Physical Society became the owner of them for the sum of *f*. 19.20 for both. Their magnifications are × 22 and × 35. The strongest lens resolves $^{1}/_{100}$ mm.

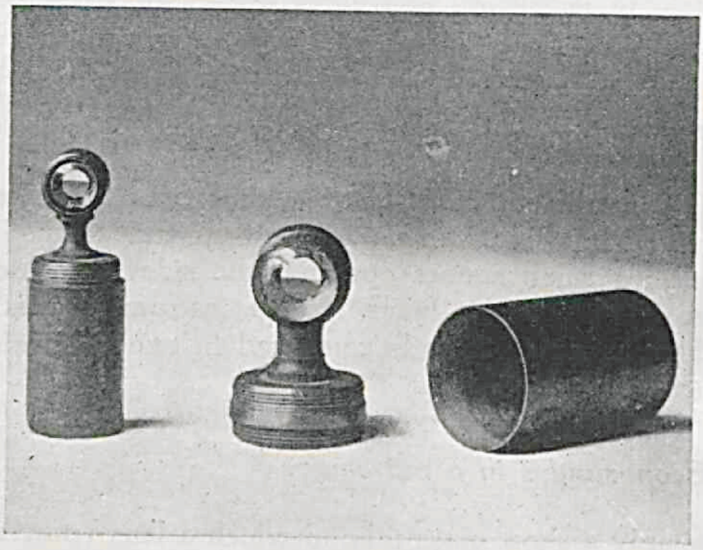

Fig. 16.

For description, resp. illustration, of Coddington lenses see, among others,

Harting III, pg. 70 resp. pl. II, fig. 3 and 4.
Petri, pg. 68.

F. 6. Holosteric lens.

Holosteric lens mounted in brass. Magnification × 12½.

CHAPTER III.

Chromatic Compound Microscopes.

G. The Culpeper microscope.

In the first half of the 18th century the English instrument-maker *Culpeper* introduced a type of compound microscope which became very popular and was copied by a great number of instrument-makers. The microscope-tube containing the objective, the field-lens and the ocular was made to fit in a second tube; for focussing it could slide up and down in this tube and so could be adjusted by hand. The outer tube was supported by three pillars between which the stage was constructed. The illuminating mirror was placed under the object stage. *Culpeper* was apparently the first to introduce this mirror in England. The original microscopes were made almost entirely of wood and cardboard. Only the supporting pillars and the stage were made of brass. Later on brass became the main material. The foot in which there was usually a drawer remained then the only part made of wood.

For a very complete descripton, resp. illustration see:

Clay and Court, pg. 108—129

and further:

Baker, pg. 15—21 resp. pl. III.
Adams, pg. 104—106 resp. pl. IV.
Harting III, pg. 141 resp. pl. IV, fig. 7.
Petri, pg. 149—152.
Cat. R. M. S., pg. 165—173. .

G. 1. Original Culpeper microscope.

This instrument is made of wood and of cardboard covered with shagreen. It is exactly the same as the microscopes described and depicted in

Clay and Court, pg. 115, fig. 75
Cat. R. M. S., pl. II A 4.

Three brass pillars, fixed in a round wooden foot, carry the stage from which three more pillars, alternating with the first three, rise to support the body-tube in which the microscope-tube can be slid up and down (fig. 17).

The instrument itself is not signed, but the Culpeper "tradecard" is fastened in the pyramidal case belonging to it.

The microscope is accompanied by the usual accessories such as:

spring object holder
illuminating lens screwed on to the stage
ivory cone with diaphragms
objectglasses in brass mounts
fish plate
live box.

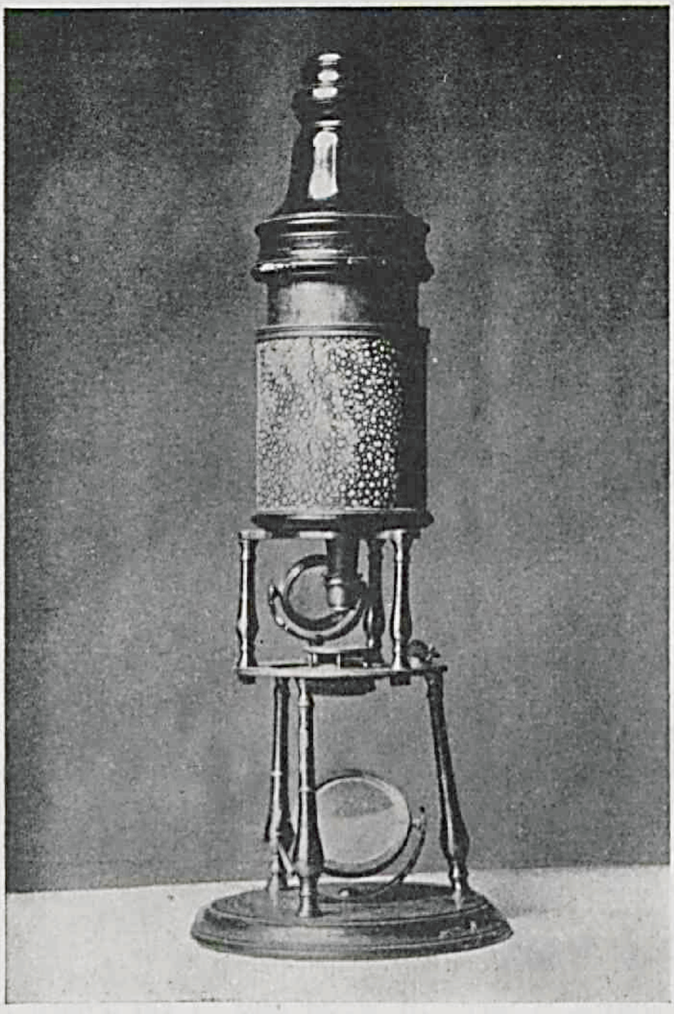

Fig. 17.

The microscope-tube is marked with dotted lines indicating the positions of the tube with relation to the body-tube required for sharp focussing with the various objectives. The 5 objectives belonging to the instrument have the following magnifying and resolving powers:

Obj:	Magn. p.	Res. p.
1	× 275	$^1/_{200}$ mm
2	100	$^1/_{100}$ „ „
3	80	$^1/_{100}$ „ „
4	60	$^1/_{100}$ „ „
5	28	$^1/_{100}$ „ „

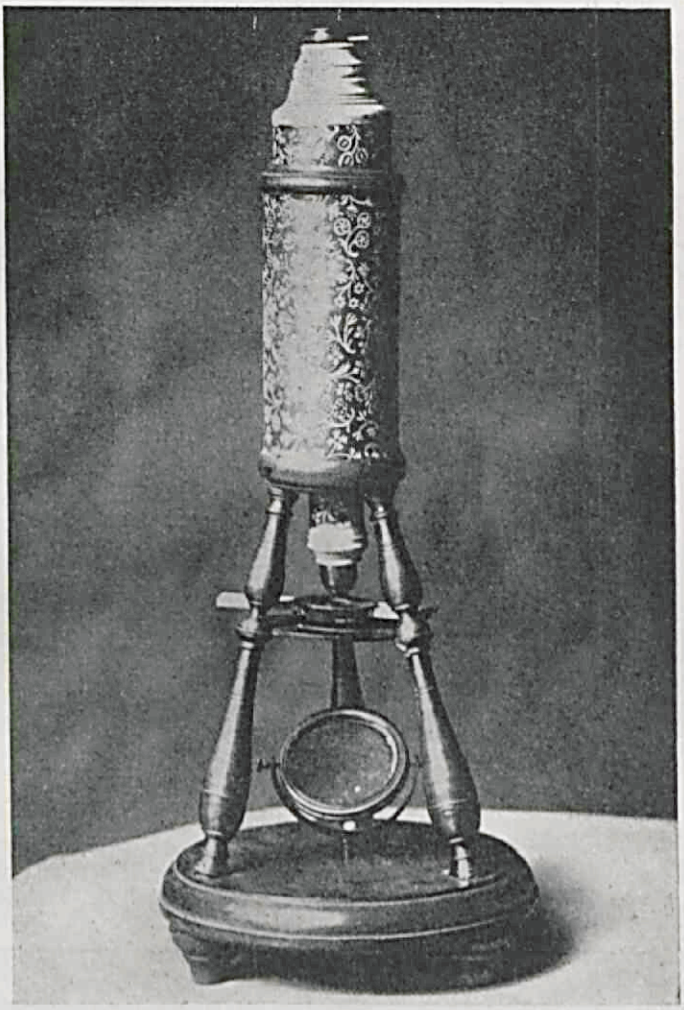

Fig. 18.

G. 2. *Culpeper microscope.*

Like the instrument just mentioned under G.1. this one is built for the greater part of wood and cardboard. It differs from the first however, in that the foot, which has a drawer, is octagonal and that it has one set of three legs extended so as to support the body-tube instead of two sets of three legs alternating at the stage. The case is missing. The microscope is exactly similar to those figured in Clay and Court, pg. 118 fig. 78 and in Cat. R. M. S., pl. V A 7. The accessories still left are: a spring objectholder and a shaft with sharp point and clamp; special clips for small glass tubes are attached to

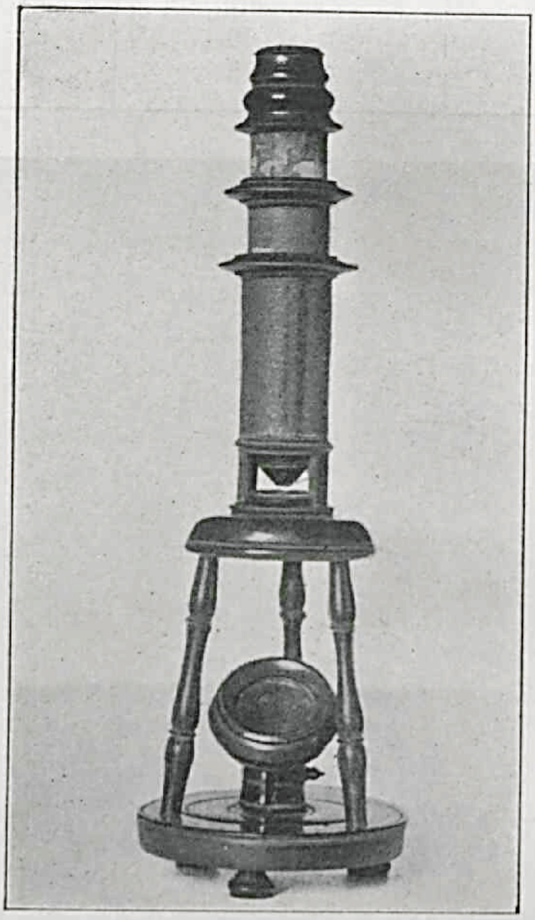

Fig. 19.

the stage. The five objectives belonging to the instrument have the following magnifying and resolving powers:

Obj.	Magn. p.	Res. p.
1	× 275	1/200 mm
2	175	1/200 „ „
3	75	1/100 „ „
4	45	1/100 „ „
5	30	—

G. 3. Culpeper microscope.

Three brass legs fixed on a round wooden foot support the body-tube of this instrument, made very primitively of cardboard ornamented with a flowery design. The lenses belonging to it are fitted in ivory mounts (fig. 18). The magnifying power is × 15. Besides these, there are an object-holder with spring-clamping and a pyramidal case.

G. 4. Nuremberg microscope.

This is one of the many instruments of wood and cardboard made in Germany during the 18th century (Fig. 19). They were mostly manufactured by preachers. (Cp. U. 5).

When the microscope-tube is drawn up to a certain mark out of the body-tube the magnifying and resolving power of the instrument are × 80 and $^{1}/_{100}$ mm. The mark *IM* is branded into the bottom of the foot.

G. 5. Brass Culpeper microscope, small model.

This instrument is constructed on lines exactly similar to those of the original Culpeper microscope but contrary to the latter this one is, with the exception of the foot, made entirely of brass. The accessories accompanying it are:

objectholder with spring-clamping
small shaft with forceps and small ivory plate
pincers
fish-plate
wooden slide for objects mounted in ivory caps
clips for small glass tubes
pyramidal case.

Originally there were 4 objectives belonging to the instrument. The lenses of those numbered 1 and 3 however are now missing, while the lens of number 2 is damaged. The power of the remaining number 4 is × 30.

G. 6. Brass Culpeper microscope.

This instrument is mounted on a square foot, containing a drawer. It is kept in a pyramidal case. Its accessories are:

object-holder
illuminating lens
clips for glass tubes
sliding tube fitted with a Lieberkuehn mirror
brass diaphragm cone
small pointed shaft with forceps

and in addition, 5 objectives of which the magnifications and resolving powers are:

Obj.	Magn. p.	Res. p.
1	× 250	1/400 mm
2	105	1/200 „ „
3	60	1/100 „ „
4	44	1/100 „ „
5	27	—

The image obtained with No. 1. is, considering, a very good one.

G. 7. *Brass Culpeper microscope.*

This instrument is signed *"J. Scarlet, London"*. It is mounted on

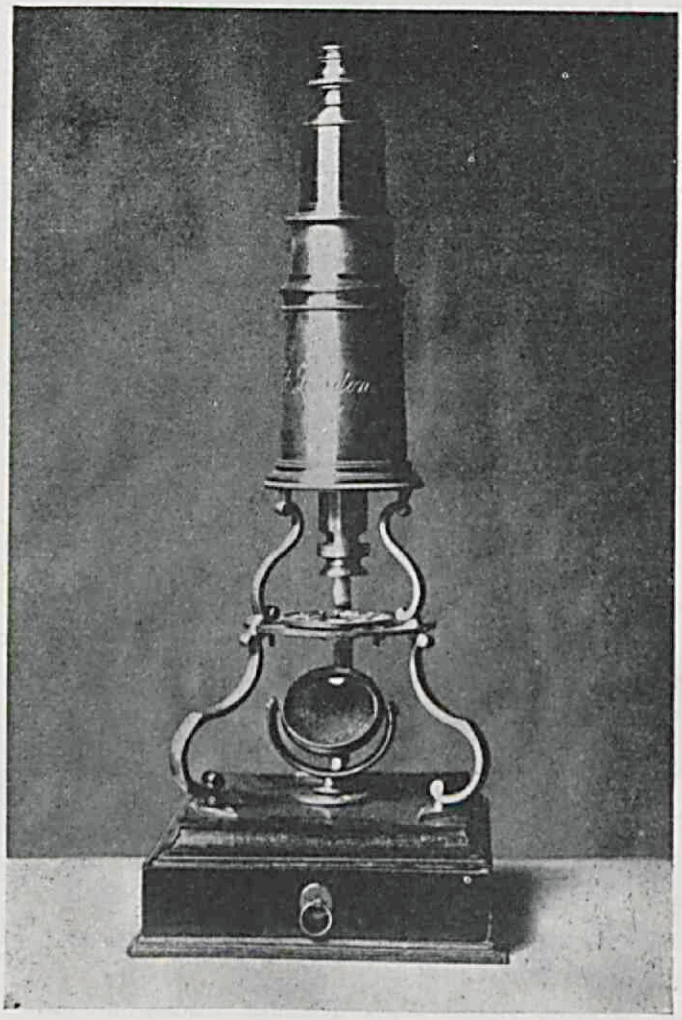

Fig. 20.

a square foot, with drawer, and is kept in a pyramidal case (fig. 20).

The accessories accompanying it are:

revolving object holder
sliding-tube fitted with a Lieberkuehn mirror
brass diaphragm cone
fish plate
live box

and also 5 objectives with the following magnifications and resolving powers:

Obj.	Magn. p.	Res. p.
1	× 200	$^1/_{200}$ mm
2	75	$^1/_{100}$ „ „
3	55	$^1/_{100}$ „ „
4	25	$^1/_{100}$ „ „
5	15	—

The image obtained with No 1. is rather poor.

G. 8. Brass Culpeper microscope.

The microscope bears the inscription *"Urings fecit"*. The pyramidal case in which it is kept is marked with the tradecard of the dealer and gives the following information concerning him, in quaint old Dutch:

"*Anthonie Ciquino* woond in de Nes, in de Weyde Lombaertsteeg, "in de Drie Weerglazen, 't Amsterdam.

"Maakt, Verkoopt en Versteld alle Zoorten van Barometers en "Thermometers, Verkoopt ook veelderlei Zoorten van Verrekijkers, "Optica-, Gezigt- en Experientie-Glaazen, Tot een çiviele Prijs."

Which in modern English runs as follows:

"*Anthony Ciquino* lives in the Nes," (an old part of the town of Amsterdam) "in the broad Lombaert-alley, in the "Three Weather- "glasses" at Amsterdam.

"Makes, sells and repairs all kinds of barometers and thermometers, "sells also a great variety of field-glasses and glasses for optical "experiments, at moderate prices."

The accessories accompanying this microscope are:

economyglass
spring object-holder
sliding tube with Lieberkuehn mirror
fish-plate
handle for the objectives, when used as ordinary magnifying-glasses, and, finally, 5 objectives. The field-lens of the microscope however is missing and for this reason there would be no sense in determining the magnifications and resolving-powers.

H. The Cuff microscope.

The two main drawbacks of the Culpeper type of microscope are the inconvenient position of the stage between the three supporting-legs, which interfere with the adjustment of the objects and of the accessories, and the primitive way in which the focussing is effected. These induced *Cuff* to devise and construct a new model. The characteristic feature of this instrument, which, like that of Culpeper became exceedingly popular, is the attachment, by means of an arm, of the tube to a rectangular pillar which can be slid along another similar pillar, fixed on the foot, while gripping it tighty. For focussing, a rough adjustment is obtained by shifting the sliding pillar by hand to its approximately correct position. To facilitate this, numbered notches are engraved on the fixed pillar indicating the position required when the objective with the corresponding number is used. After clamping the sliding pillar to the fixed one, the final focussing is effected by means of a screw. *Cuff* made the stage in the shape of a Maltese cross, in the corners of this cross are holes in which the condensing lens, the fish plate etc. can be fixed. On the snout (microscopic-tube) slides an outer tube on to which the lieberkuehn was screwed. Numbered notches on the microscope-tube denote the position of this outer tube required to concentrate the reflected light on the objects underneath. This type of instrument is described, resp. illustrated in:

Adams, pg. 89—92 resp. pl. VII A.
Harting III, pg. 142—143 resp. pl. IV fig. 8.
Petri, pg. 153—154.
Clay and Court, pg. 136—154.

H. 1. Cuff microscope. (Small model).

This instrument differs greatly from the general type described above. It is mounted on an oval brass plate which is fixed on a mahogany foot (fig. 21). The stand is attached to the brass foot by means of a compass-joint. The microscope itself which is made of wood and of shagreen covered cardboard can be replaced by a simple microscope and is illustrated as such in Clay and Court fig. 42 and in Petrus van Musschenbroek: *Introductio ad Phil. Nat. II, Tab. XLV.*

Neither the instrument nor the case are signed. The Science Museum in London however, is in the possession of a model exactly similar, of which the case, too, has precisely the same division, and this case is signed *"Cuff"*. This practically guarantees the authenticity of our instrument.

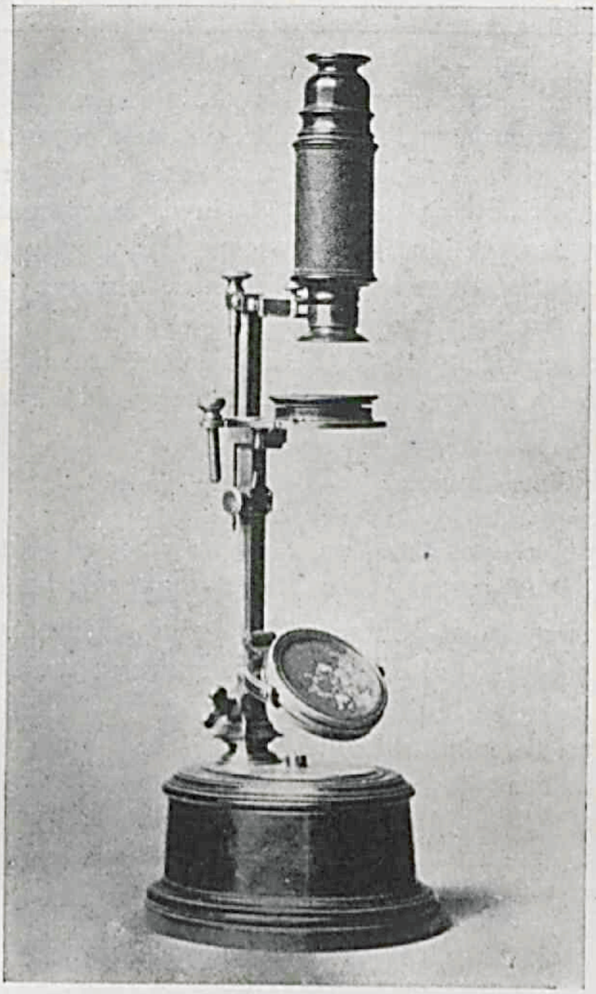

Fig. 21.

The illuminating-mirror as well as the stage and the body itself can be folded back against the pillar. The microscope has aquatic motion. The illuminating-mirror is hollow on the one side and plane on the other.

As a simple microscope four objectives belong to it, fitted with ivory protection caps. These four can be combined by screwing one on top of the other. This arrangement, however, gives very poor images. The magnification and resolving-power of the various lenses are

Lens	Magn. p.	Res. p.
1	× 140	$^1/_{400}$ mm
2	110	$^1/_{200}$ „ „
3	65	$^1/_{200}$ „ „
4	52	$^1/_{200}$ „ „

As a compound microscope it has a sliding tube and two objectives, both of which are constructed in lieberkuehns. When the tube is slid in, the magnifications of the objectives are × 45 and × 100, the resolving power of both of them is $^1/_{100}$ mm. On comparing this power with the values for the simple microscope the superiority of the latter is evident at once. Moreover, the images given by the compound microscope are strongly chromatic.

The accessories belonging to the instrument are: live box, fish plate and a screw to fix the oval brass foot directly on the table.

H. 2. Cuff microscope.

This microscope is mounted on a square wooden foot with a drawer in it (fig. 22). It is signed *"Geo Sterrop, maker"*. Its accessories are:

two object-holders, with spring clamping.
a black and white disc for putting the object on.
a ground glass object carrier.
an illuminating lens
a brass diaphragm cone
a small sharp pointed shaft
a lieberkuehn tube
a fish plate
a live box
a pyramidal case with drawer.

In addition it has 6 objectives of which the magnifying and resolving powers are resp.

Obj.	Magn. p.	Res. p.
1	× 220	$^1/_{200}$ mm
2	160	$^1/_{200}$ „ „
3	70	$^1/_{100}$ „ „
4	56	$^1/_{100}$ „ „
5	42	$^1/_{100}$ „ „
6	30	—

H. 3. Cuff microscope.

This instrument which bears no signature is remarkable for its stage which differs from the usual type by its oblong shape. A further curious detail is the mounted condenser, belonging to the instrument, which can be fitted in the hole in the stage. The object holder with

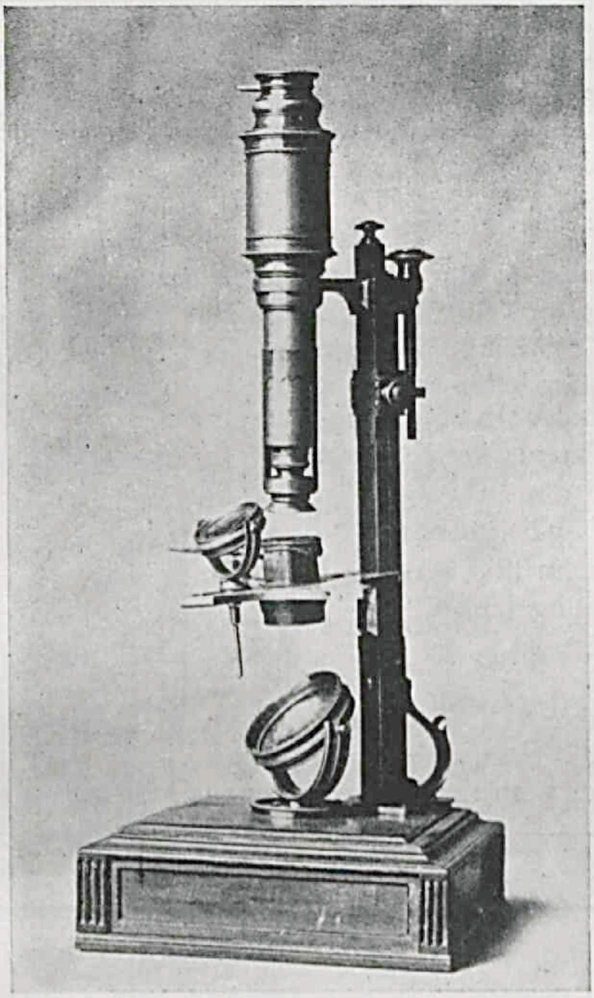

Fig. 22.

spring-clamping and the diaphragm-cone are combined to make one single piece. Further accessories are:

illuminating lens
little glass tubes
lieberkuehn tube
pyramidal case

and 6 objectives with the following magnifications and resolving powers:

Obj.	Magn. p.	Res. p.
1	× 200	1/200 mm
2	100	1/200 „ „
3	80	1/200 „ „
4	37	1/100 „ „
5	28	1/100 „ „
6	19	—

The lens of objective 3 is plano-convex. The image obtained by No. 1. is badly distorted and chromatic.

H. 4. Cuff microscope.

This instrument is signed *"Lincoln, London"*. Its strongest feature is its resolving power which far exceeds the average of the other non-corrected compound microscopes.

The accessories belonging to it are:

- object-holder with spring-clamping
- small sharp-pointed shaft with forceps and a black and white disc
- brass diaphragm cone
- lieberkuehn tube
- illuminating lens
- fish plate
- live box
- glass tubes
- pyramidal case with drawer

and 6 objectives with the following magnifying and resolving powers:

Obj.	Magn. p.	Res. p.
1	× 145	1/400 mm
2	85	1/200 „ „
3	40	1/100 „ „
4	40	1/100 „ „
5	28	1/100 „ „
6	20	—

H. 5. Cuff microscope.

This instrument is signed *"B. Martin et fils, fecit"*.

In strong contrast to H. 4, the resolving power of this instrument remains far beneath the average. Besides, of the 5 objectives belonging to it, 4 are, practically speaking, equally strong. Its accessories are:

object-holder with spring clamping
lieberkuehn tube
brass diaphragm cone
revolving object-holder
small sharp pointed shaft with forceps and a black cap
double illuminating mirror

and besides 5 objectives of which the magnifications and resolving powers are respectively:

Obj.	Magn. p.	Res. p.
1	× 80	$^1/_{100}$ mm (barely)
2	38	—
3	32	—
4	30	—
5	27	—

H. 6. Cuff microscope.

This is a very primitive instrument differing greatly from the standard type. It is in all probability the work of some of the wards of the "van Renswoude" foundation. A vertical grooved stand of brass is fixed on a round wooden foot. In the groove the arm bearing the microscope can be slid up and down and is adjustable by means of a screw. The instrument is constructed without a field lens. The illuminating mirror is missing. The remaining accessories are a spike for fixing the objects and four objectives. One of the latter however is without a lens. The magnifying powers of the others are × 100, 56 and 32. The images obtained by them are very poor. The strongest objective is hardly able to resolve $^1/_{100}$ mm. To the instrument there belongs a very coarsely finished pyramidal case with a drawer.

H. 7. Cuff microscope differing widely from the standard type.

This instrument is remarkable for the way it combines some features of the Cuff microscope with some of the Culpeper type. A round brass pillar is fixed on a square foot with a drawer in it. To the pillar the stage is attached sideways and also the body-tube in which the microscope-tube, exactly as in the Culpeper type, can be slid up and down, with this difference that the sliding is not effected by hand in this case, but by rack and pinion (fig. 23).

Its accessories are:

object-holder with spring clamping
live box

small shaft with sharp point and clamp
pyramidal case with drawer
5 objectives with the following magnifications and resolving powers:

Obj	Magn. p.	Res. p.
1	× 180	1/200 mm
2	280	1/100 ,, ,,
3	58	1/100 ,, ,,
4	42	1/100 ,, ,,
5	32	1/100 ,, ,,

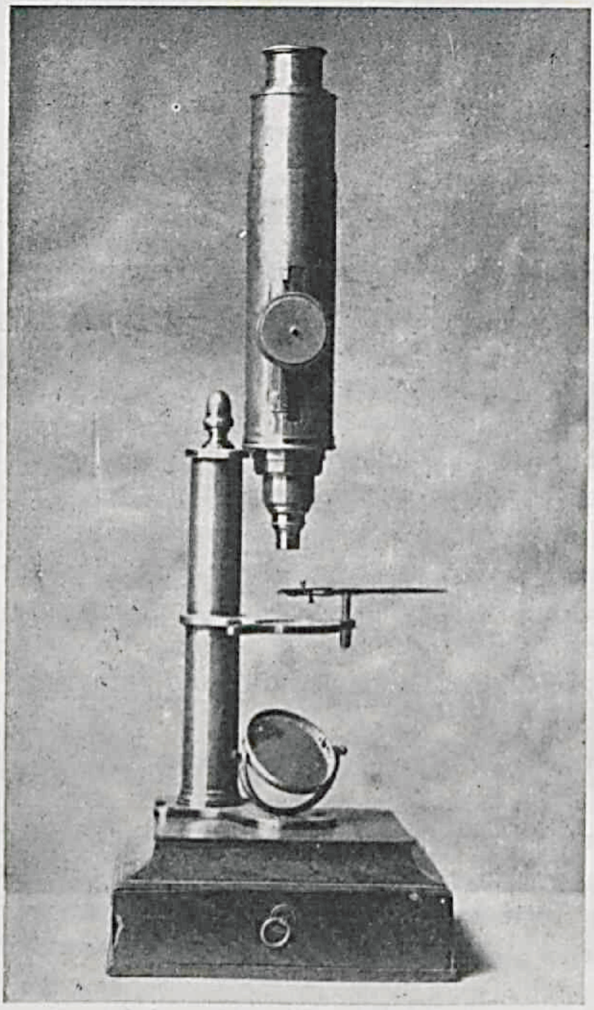

Fig. 23.

No. 1 gives a distorted image. The image obtained with No. 2. is exceedingly poor. Its present lens was evidently put in at a later date and did not belong to this microscope.

H. 8. Cuff microscope differing widely from the standard type.

This is more or less similar to the one described onder H. 7. The object-holder with spring-clamping and the diaphragm-cone are made in one piece. Various accessories are missing; all that is left of them is a small sharppointed shaft with forceps and four objectives with the following particulars:

Obj.	Magn. p.	Res. p.
1	— lens missing	—
2	× 100	$^1/_{200}$ mm
3	95	$^1/_{200}$,, ,,
4	46	$^1/_{100}$,, ,,

The objective lenses are plano-convex, their convex surfaces however are turned towards the side of the object.

I. The microscope of Dellabarre.

About the year 1770, *Dellabarre* built a microscope which, according to him, had many advantages over the existing types. In the first place, according to him, the images were achromatic owing to the fact that the eyepiece of his construction consisted of several lenses made of different kinds of glass. In the second place, the numerous combinations made possible by intercombining four ocular lenses, three objectives and a long or short microscopic-tube, were supposed to offer many advantages too. According to the inventor, the images were splendid in quality and a magnification of 23110272000 could be reached. This enormous value was meant as a three-dimensional!

In reality, however, the instrument did not nearly achieve what it was supposed to. The four ocular lenses were all of them bi-convex, and could therefore never be combined so as to form achromatic sets. Besides, if one tries to obtain higher magnifications by combining ocular lenses of the strength of 80 dioptries instead of by making the objective stronger, one can never expect an increase of the resolving power.

For an elaborate description, (resp. illustration) see:

Baker, pg. 442—458 resp. pl. XXV.

Further:

Harting III, pg. 154—158 resp. pl. V fig. 2.
Petri, pg. 162—163.
Cat. R.M.S., pg. 205—207.
Clay and Court, pg. 204—207.

The microscope was constructed as follows: On a tripod was mounted a square brass stand along which the illuminating mirror (plane on one side and hollow on the other), the condenser and the stage could be slid. They could all three be folded and rotated sideways out of the optical axis. The up and down motion of the stage was effected by rack and pinion. The microscope, clamped in a ring, hung at the end of an arm which was attached to the stand so as to be capable of "aquatic" motion. The microscope was comparatively short, it could however, be lengthened by an auxiliary tube. Four ocular lenses and 3 objectives belonged to the instrument. The four ocular lenses could either be combined into one system, or each one of them could be made to play the part of a field-lens while the other three could be combined in various ways to an eyepiece. Over the eyepiece an eye-ring was fixed, but as early as in the translation of Baker's work it is stated that the latter was practically never used, and indeed, observations made with the microscope described below under I. 1. confirmed the utter impractability of this eye-ring!

The upper part of the metal stand together with the microscope and the stage could pivot round a compass joint, so that the instrument could be used in a horizontal arrangement as well. The whole instrument made an unwieldy impression and its mechanism left much to be desired!

I. 1. Dellabarre microscope.

The construction of this instrument agrees in every way with *Baker's* description, mentioned above. The various parts are even marked with the same letters as those given to them in the description, (fig. 24). The accessories include a large Lieberkuehn mirror and an object-holder of a special make to be used in the horizontal arrangement. Everything is contained in a mahogany box. Three objectives and four eyepiece lenses belong to the instrument as well. Although *Dellabarre,* in his original description, states emphatically that the objective lenses are plano-convex, with their plane surfaces turned towards the object, in reality the lenses here are bi-convex. The eyepiece lenses are all different from each other. The approximate values of their optical data are as follows:

Oc.	R_1	R_2	n	f
I	6.2 cm	4.5 cm	1.5	5 cm
II	6.2 ,,	7.0 ,,	1.6	5.2 ,,
III	4.2 ,,	4.2 ,,	1.5	4.2 ,,
IV	6.2 ,,	6.2 ,,	1.7	4.5 ,,

(The refractive indices are computed from the directly measured values of the radii of curvature and the focal lengths.)

The magnifying and resolving powers which follow refer to the microscope when at its greatest length.

Objective 2.			
field-lens	eyepiecc	magnification	Res. p.
—	I+II+III+IV	× 420	$^1/_{200}$ mm
IV	I+II+III	240	$^1/_{200}$,, ,,
IV	I+II	180	$^1/_{200}$,, ,,
IV	I	110	$^1/_{200}$,, ,,

The images are strongly chromatic and for the higher magnifications very bad.

Objective 1.			
field-lens	eyepiece	magnification	res. p.
—	IV+III+II+I	× 110	$^1/_{200}$ mm
IV	III+II+I	55	$^1/_{200}$ „ „
IV	II+I	41	$^1/_{100}$ „ „
IV	I	30	$^1/_{100}$ „ „

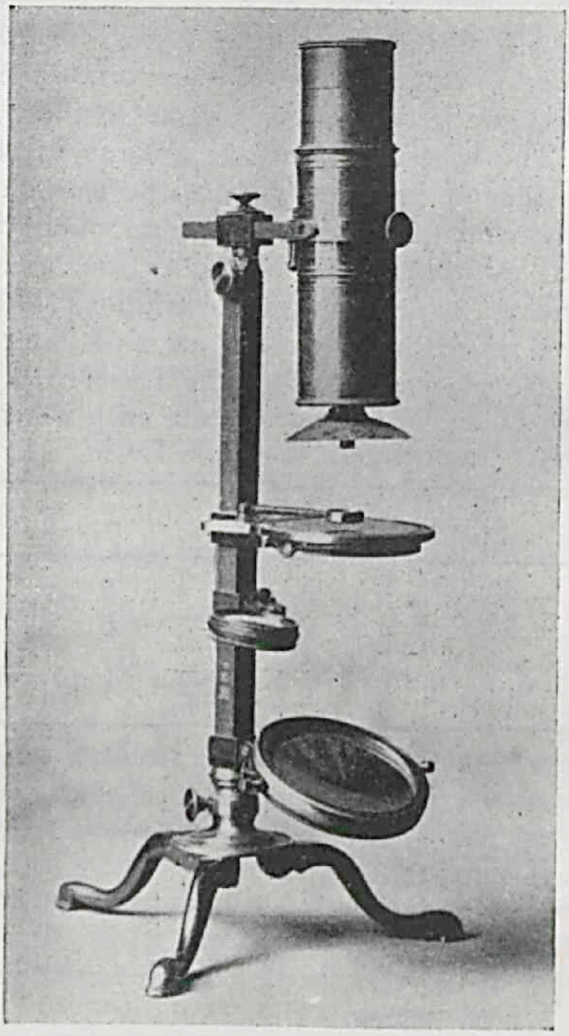

Fig. 24.

The lens of objective 3 is missing.
For the various eyepiece combinations the order of the lenses is

given in the direction from top to bottom. The eyepiece lens IV has a strong green colour.

I. 2. Microscope of Dellabarre.

The perfectly useless eyering and the equally superfluous differences between the various ocular lenses have been omitted from this microscope. It is fitted instead with a fixed field-lens of focal length 5,3 cm and 3 identical eyepiece lenses, focal length 3,8 cm, which can be intercombined. Their refractive index is about 1.6. The double illuminating mirror is made of speculum metal. Further accessories are:

Lieberkuehn mirror
shaft with forceps and sharp point
pyramidal case.

Only one objective is left. With 3, 2, resp. 1 eyepiece lens the magnification is $\times$ 27, 23 and 15 respectively. With none of the magnifications $^{1}/_{100}$ mm is resolved.

J. The Cary microscope.

In the beginning of the 19th century the English instrumentmaker *Cary* constructed a small microscope which became highly popular,

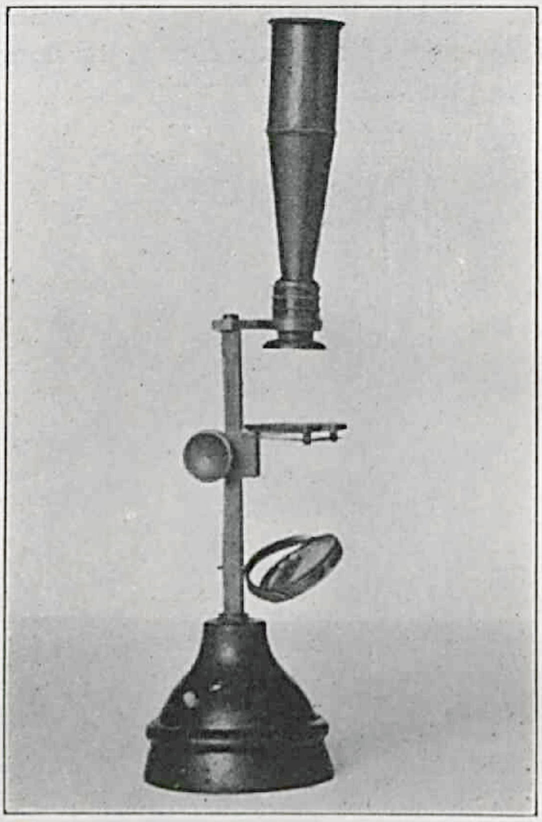

Fig. 25.

especially in England. The microscope-tube, the upper part of which was cylindrical and the lower part conically narrowing was fixed rigidly to the stand. The focussing was therefore effected exclusively by the up and down motion of the object by means of rack and pinion. The microscope was fitted with various objectives which could be used either separately or in combination. The eyepiece lens and the field-lens were fitted to form, as is still done nowadays, one single sliding piece. For description see for instance:

Cat. R.M.S., pg. 220—225 (figure on plate 21).

J. 1. Cary microscope.

This small instrument mounted on a round wooden foot bears the signature „*Cary, London*", (fig. 25). To the lower end of the microscope carrier is attached a small plane-convex lens in the centre of a Lieberkuehn mirror. There are also three bi-convex objective lenses and inside the microscope tube there is still another little lens with a conical wooden mount. The mounting is however so primitive that the adjustment of this lens in the optical axis of the instrument is practically impossible. This complication makes all efforts to obtain images of a fairly good quality unsuccessful. It is very doubtful whether this lens really belonged to the instrument originally at all.

The eyepiece is a doublet consisting of two bi-convex lenses. When used as a simple microscope the lens (L) mounted in the Lieberkuehn gives a magnification × 24 and resolves $^1/_{200}$ mm.

Used as a compound microscope the magnifying and resolving powers are:

Obj.	Magn. p.	Res. p.
L	× 120	$^1/_{200}$ mm
L+1	145	$^1/_{200}$ „ „
L+2	135	$^1/_{200}$ „ „
L+3	130	$^1/_{200}$ „ „
1	46	$^1/_{100}$ „ „
1+2	78	$^1/_{100}$ „ „
1+2+3	92	$^1/_{200}$ „ „
2	27	—
2+3	52	$^1/_{100}$ „ „
3	17	—

Some of the combinations give strongly chromatic images.

J. 2. Cary microscope.

This microscope, of which the illuminating mirror is missing, is mounted on a wooden box. Accompanying the instrument there are three objectives allowing of combinations with magnifying and resolving powers as follows:

Obj.	Magn. p.	Res. p.
1	× 21	—
1+2	39	1/100 mm
1+2+3	52	1/200 „ „
2	15	—
2+3	30	1/100 „ „
3	9.5	—

Like those of the instrument just mentioned some of these combinations give strongly chromatic images too.

K. Miscellaneous.

K. 1. Microscope made of palm-wood.

With the exception of the hoop bearing the body of the microscope and of the stage, this instrument is made entirely of wood. The stand is fixed on a large mahogany box; to this stand the brass hoop is

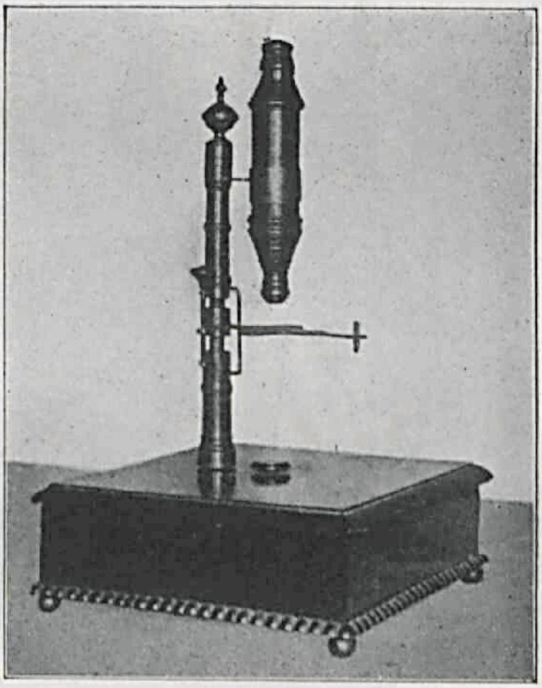

Fig. 26

attached in which the microscopic tube can be made to slide up and down by hand. For sharp focussing the stage is adjusted by means of a screw (fig. 26). The illuminating mirror is missing and of the original objectives only No 5. is left. Its magnifying power is $\times$ 40, but the images are strongly distorted and it cannot resolve even so much as $^1/_{100}$ mm.

K. 2. Microscope of Martin.

This large microscope bears the engraving

"B. Martin Invt. et fecit. London."

It is very much like the instrument described and figured in
Cat. R.M.S. pg. 201 resp. pl. 16. and
Clay ond Court pg. 194—197
only it is much less decorative (fig. 27). A square bar is fixed on a

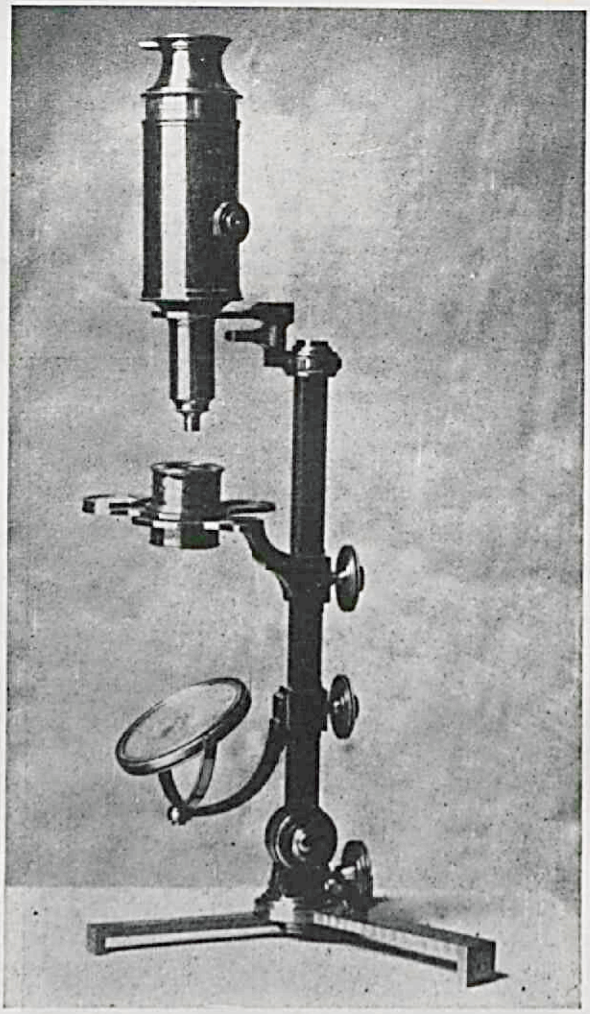

Fig. 27.

folding tripod. The upper end of the bar carries the microscope which can pivot on a joint. That bar can be inclined, according to need, by means of a worm. The double illuminating mirror as well as the stage can be made to slide along the stand-bar by means of rack and pinion. The microscope itself is, optically speaking, remarkable: between the field-lens and the objective is fitted another lens, a bi-convex one, of power 4,5 *D* which is called the ,,between-lens". The distance objective—"between-lens" amounts to 6.5 cm. The eye-piece consists of two lenses, 8 cm apart, viz: a plano-convex ocular lens (power 16 *D*) and ditto field-lens (power 10 *D*) and can be made to slide over a range of 6.5 cm, so that the distance field-lens

—between-lens can be varied from 5 to 11.5 cm. The between-lens was evidently put in to intensify the influence of the field-lens, for it enlarges the field of view at the cost of the magnification. Both eye-piece lenses are mounted with their plane surfaces turned towards the eye.

Of the objectives only No. 2 is left. The various optical data of the instrument are:

	magnif.	resolving p.	field of view.
a. with the between-lens			
tube pushed in	× 47	1/100 mm	2¼ mm
tube drawn out	85	1/100 „ „	2 „ „
b. without the between-lens			
tube pushed in	× 65	1/100 mm	1¾ mm
tube drawn out	90	1/100 „ „	1½ „ „

All other accessories are missing except a loose triple object-carrier that can be fixed on the stage.

K. 3. Compound microscope.

This small microscope, elegantly finished off and contained in a morocco-leather case differs in mechanical as well as in optical respect from all the other microscopes of the collection.

On a folding tripod are mounted the illuminating mirror, and an octagonal tube (fig. 28) in which a round steel rod can be made to slide over a small range by means of a screw immediately above the foot. Over this steel rod a brass tube can move up and down and can be clamped tight to the rod at any desired height by a screw. At its upper end this tube carries the microscope.

The coarse focussing is effected by moving the round tube over the steel rod by hand and, after clamping it for the final adjustment, the steel rod is moved by means of the lower screw in the octagonal tube.

The stage is attached to the octagonal tube; it can be removed and replaced by an arm which carries a little shaft movable in all directions and with a forceps at one end and a black-white disc at the other.

The microscope contains, besides the usual lenses, the "between-lens", mentioned under K. 2. This is a plano-convex lens with its flat side turned up and fitted at such a height that the eyepiece is focussed exactly on this flat surface so that the image of a micrometer if placed on this surface is seen sharp, together with the image of the object.

There were, originally, 5 objectives with the instrument. One of them is mounted in a lieberkuehn mirror (L). The others were marked 1—4. No 1, however, is missing. The objectives can be used as a simple microscope too. For that purpose an eye-cap can be fitted above the objective in question.

The optical powers are as follows:

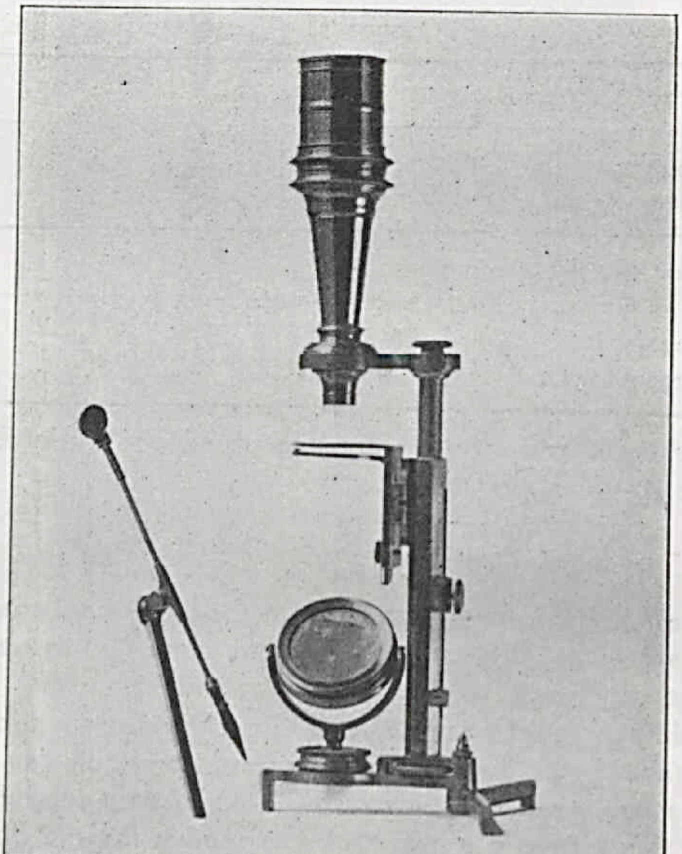

Fig. 28.

Obj.	Simple		Compound	
	Magn.	Resolv. p.	Magn.	Resolv. p.
L	× 50	1/200 mm	× 105	1/200 mm
2	38	1/200 „ „	80	1/200 „ „
3	30	1/100 „ „	65	1/100 „ „
4	19	1/100 „ „	40	—

Here is once more a convincing demonstration of the superiority of the simple microscope. The same lens which as a simple microscope resolves $^1/_{100}$ mm. with a magnification of 19 is not able as part of a compound microscope to resolve this $^1/_{100}$ mm with a magnification of 40.

The microscope is not signed. The foot, however, is marked *"Da"*.

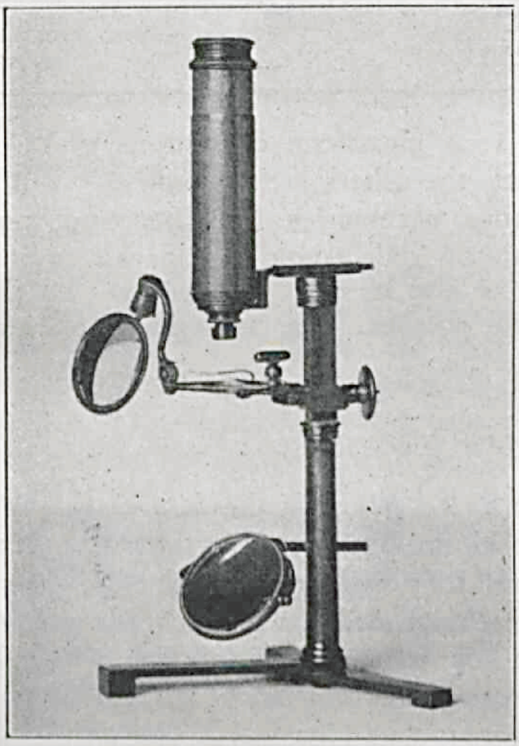

Fig. 29.

K. 4. Small microscope of Eastland.

This comparatively small instrument is signed

"Eastland & Comp. London."

It is mounted on a folding tripod. The microscope itself has aquatic motion. The focussing is effected by rack and pinion adjustment of the stage. The latter is fitted with two clips and an illuminating lens is attached to it by means of a hinge and ball socket joint so that it can be turned in any direction (fig. 29).

The eyepiece is a doublet of which both lenses are bi-convex. When fitted in a special holder, included among the accessories, it can be used separately as a simple microscope and, as such, its magnification is $\times$ 17 and its resolving power $^1/_{100}$ mm.

The eyepiece tube can be slid up and down in the microscope tube and is marked with a notch. When the eyepiece is drawn out as far as this notch the 4 objectives belonging to the instrument have the following magnifying and resolving powers:

Obj.	Magnif.	Res. p.	Remarks.
1	× 210	1/200 mm	image average
2	310	1/200 „ „	image hazy
3	320	1/400 „ „	
4	250	1/400 „ „	strongly chromatic

Objective No 1. is plano-convex and its plane surface is turned towards the object; the others are bi-convex.

Besides numerous accessories for dissecting purposes there is a stray tube with an object-holder attached to it and in which a second tube can be slid by rack and pinion. To the latter tube the objectives and the eyepiece can be screwed on and the instrument held simply in the hand.

K. 5. Compound microscope.

To judge from its construction the date of this instrument must be about the middle of the 19th century though it is not achromatized. On a round metal foot two vertical bars are fixed between which the stage can move up and down by rack and pinion. These bars are connected at the top by a horizontal slab which carries a tube in which the microscope tube can slide up and down. To this slab is also attached a condensing lens which can move in all directions by means of a double ball-socket joint. The 3 objectives accompanying the instrument are bi-convex, the lenses of the eye-piece, however, plano-convex, with their plane surfaces turned towards the eye. The resolving power is considerably greater than that of the compound microscope described above, a fact which must be solely ascribed to the better workmanship bestowed on the lenses.

Obj.	Magn. p.	Res. p.
1	× 25	1/100 mm
2	50	1/200 „ „
3	75	1/200 „ „

CHAPTER IV.

Achromatic Compound Microscopes.

L. Achromatic objective of Beeldsnijder.

This objective was found by *Prof. Harting* among microscopes and accessories in a box which had originally belonged to *François Beeldsnijder.* [1]) According to *Harting* it must have been made by *Beeldsnijder* himself somewhere about 1791, a time when he was engaged in the construction of microscopes. It consists of three lenses fitted in a short brass tube, and of which the optical centres are very closely collinear. The two outer lenses are bi-convex and are made of crown glass, between them is placed a bi-concave lens of flint glass. The first two lenses have focal lengths of 22 resp. 19 mm, the focal length of the third one is 20 mm, the focal length of the system amounts therefore to about 21 mm. The thickness of the 3 lenses together amounts to about 4 mm. Their diameter is 6.5 mm. When combined with the weakest eyepiece of Hartnack (Q. 3) it can resolve $^{1}/_{100}$ mm while the magnification is still as low as 20, an achievement which cannot be obtained by any of the compound microscopes described above nor exceeded by the simple microscope either.

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[1]) *François Gerardzoon Beeldsnijder* was born in 1755 and died in 1808. He was a colonel in the Amsterdam cavalry, a member of the committee of Justice in that town and collecter of burial rates of St. Anthony's churchyard. He used to spend much of his time in experimenting in physics and mechanics as an amateur.
Cp: Harting III pg. 168—169
Petri pg. 165—166.

M. Achromatic microscopes of van Deyl.

The Amsterdam instrumentmaker, *Harmanus van Deyl* (born in 1738), was the first to introduce achromatic microscopes on the market. In a communication to the *Physical papers of the Royal Society of Sciences at Haarlem III, 2nd. vol, page 133, 1807 (Natuurkundige Verhandelingen van de Koninklijke Maatschappij der Wetenschappen te Haarlem III, 2e deel, pg. 133, 1807*) he states that he and his father *Jan van Deyl*, (born in 1715, and died in 1801) had already constructed an achromatic microscope as early as 1770. They had, however not advertised their success, being at the time too busy making achromatic fieldglasses (telescopes) and because they expected others would succeed ere long in the construction of the same microscope.

Harmanus van Deyl then proceeds to give a description of the achromatic microscope which he had just made for the market. The stand was very sober in design; the utmost care, however was bestowed on the lenses. The optical equipment of the microscope consisted of two achromatic objectives with focal-lengths $^{11}/_{10}$ "duim" (= 26 mm) and ¾ "duim" (= 18 mm) and two eyepieces. The objectives were composed of a plano-convex flint-lens and a bi-convex crown-lens. The plane surface of the first was turned towards the side of the object. The two eyepieces were bi-convex but their surface on the side of the eye was considerably less curved than the other one. The microscope-tube could be lengthened by drawing out the inner tube. The magnifying power of the weaker objective combined with the weaker eyepiece was, with the tube pushed in, × 25 and reached × 45 when the tube was drawn out (these magnifications are determined for 20 cm distance). Combining the weaker objective and the stronger eyepiece, as well as the stronger objective and the weaker eyepiece, these values ranged from × 45 to × 80 and finally, for the combination of the stronger objective and stronger eyepiece, from × 40 to × 150.

In Harting III pag. 170—174 this instrument is described in detail. According to Harting it was possible to combine the two objectives, thereby increasing the resolving power so as to be able to resolve even the third group of a Nobertplate (0.0016 mm).

M. 1. Microscope of van Deyl.

This instrument is signed:

"Harms van Deyl
Inv = et Fecit
Amsterdam."

It is accompanied by a very complete handwritten description. Its mechanical construction is very simple and in many respects does not reach the high standard of the instruments of the 18th century. The illuminating mirror is fastened on a folding tripod, as is also a brass bar in the groove of which the stage can be moved up and down by means of a pinion. At the upper end of the bar the microscope is attached in such a way that it can be moved by hand in any direction over the stage (aquatic motion).

Accompanying the instrument there are also the two achromatic objectives and the eyepieces. The weaker eyepiece, however, contains a bi-convex lens with equal curvature on both sides; it, therefore, evidently does not belong to the instrument; nor does the magnification obtained with it agree with the one given in the accompanying description. Strange to say, the instrument is constructed *without a field-lens.* Further information concerning the objectives cannot be given as they are mounted in such a way that they cannot be taken to pieces. Cleaning the lenses was therefore out of the question and the following measured resolving powers only represent a lower limit. The images are indeed achromatic, only strongly distorted.

Obj.	Eyep.	Magn. p. tube pushed in	Magn. p. tube drawn out	Resolv. p.
1	1	× 100	× 175	1/200 mm
1	2	85	150	1/200 „ „
2	1	60	120	1/200 „ „
2	2	50	95	1/100 „ „

The corresponding data in the written description (recomputed, however for a distance of 25cm.) are:

Obj.	Eyep.	Magn. p. tube pushed in	Magn. p. tube drawn in
1	1	× 100	× 187
1	2	56	100
2	1	56	100
2	2	31	56

The further accessories are:

Lieberkuehn mirror
defect mount for the illuminating lens
fish plate
live box
mahogany box with drawer.

M. 2. Microscope of van Deyl.

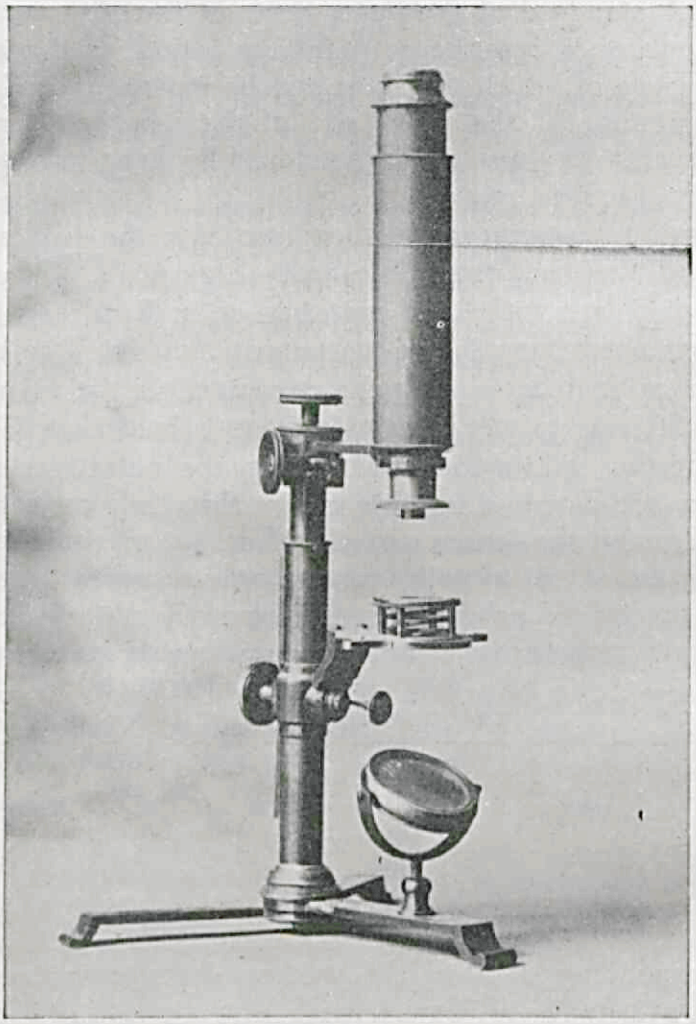

Fig. 30.

This microscope also is signed:

"Harms van Deyl
Inv et Fecit
Amsterdam."

Its mechanical parts are much better finished off that those of the instrument described under M.1. The microscope is not moved by hand over the stage but by means of a rack and pinion and by a worm (fig. 30). Contrary to the construction of M. 1 this instrument is equipped with a field-lens, which, like the eyepieces, is bi-convex, with its less-curved surface turned towards the eye. The two eyepieces are screwed on to this field-lens with tubes of different lengths.

The magnifications and resolving powers are:

Obj.	Eyep.	Magn. p. (tube pushed in)	Magn. p. (tube drawn out)	Res. p.
1	1	× 92 (100)	× 150 (187)	$^1/_{200}$ mm
1	2	50 (56)	90 (100)	$^1/_{200}$ „ „
2	1	58 (56)	100 (100)	$^1/_{200}$ „ „
2	2	32 (31)	62 (56)	$^1/_{200}$ „ „

The numbers in brackets are those given in the above-mentioned communication (corrected for 25cm. distance).

The quality of the images is very satisfactory. They are achromatic and not distorted. On comparing the resolving powers of this instrument with those of the non-achromatic types, described above, it is at once apparent that van Deyl's achievements mean a considerable step forwards. His resolving powers reach the same order of magnitude as those of the simple microscopes.

The accessories, still left are:

Lieberkuehn mirror

extra brass tube to be fitted when using this mirror with the weaker objective

object-holder

sharp-pointed shaft with clamp

mahogany box with drawer.

N. Microscope of Amici.

A very great improvement in the construction of achromatic objectives was made by the Italian professor *Amici* († 1862). He began by trying to avoid chromatic aberration by constructing objectives with concave mirrors instead of lenses (Katadioptric microscopes), but about 1830 he began to improve the achromatic objectives. He put an end to the method, which had gradually become general, of making strong objectives by combining a number of weaker lenses, each of which had been corrected separately as completely as possible. He, on the contrary, constructed objectives of which the separate parts themselves still showed strong deviations, only they were computed in such a way as to neutralize their impairing effects when combined. This method made the correction of the objectives much more satisfactory than before. *Amici* moreover, included in his considerations the thickness of the cover-glass and he was the first to make systematic use of immersion for the purpose of obtaining higher resolving powers. As a further improvement, he equipped his microscopes with a large number of eyepieces which made alteration of the magnifications possible without having to change the objectives and without spoiling the central adjustment of the object.

Finally, he constructed his microscopes with the tube horizontal which, in his opinion, facilitated observations considerably; he achieved this by placing a reflecting prism over the objective.

N. 1. Microscope of Amici.

This instrument bears the signature: „*Amici, Firenze.*"

It was bought by the "Natuurkundig Gezelschap" (Physical Society) for *f* 500. A very complete description signed by *Amici* and dated March 7th. 1836 accompanies the instrument.

It is constructed as follows (fig. 31): On a folding tripod is mounted a brass stand along which a very large concave illuminating mirror, and the stage as well, can be made to slide by rack and pinion. The horizontal microscope is attached to the upper end of the stand. The stage can be moved in two directions at right angles to each other. These displacements can be measured with the aid of two micrometer-screws of which the divisions correspond to 0.0031 mm and to

0.00246 mm (= 0.0001 inch) respectively. Directly under the stage is fitted a cone with a diaphragm-wheel with three apertures. This cone can be rotated out of the optical axis. There is, further, a small ground glass plate capable of the same rotation. A plano-convex condensing lens for the illumination of opaque objects is attached

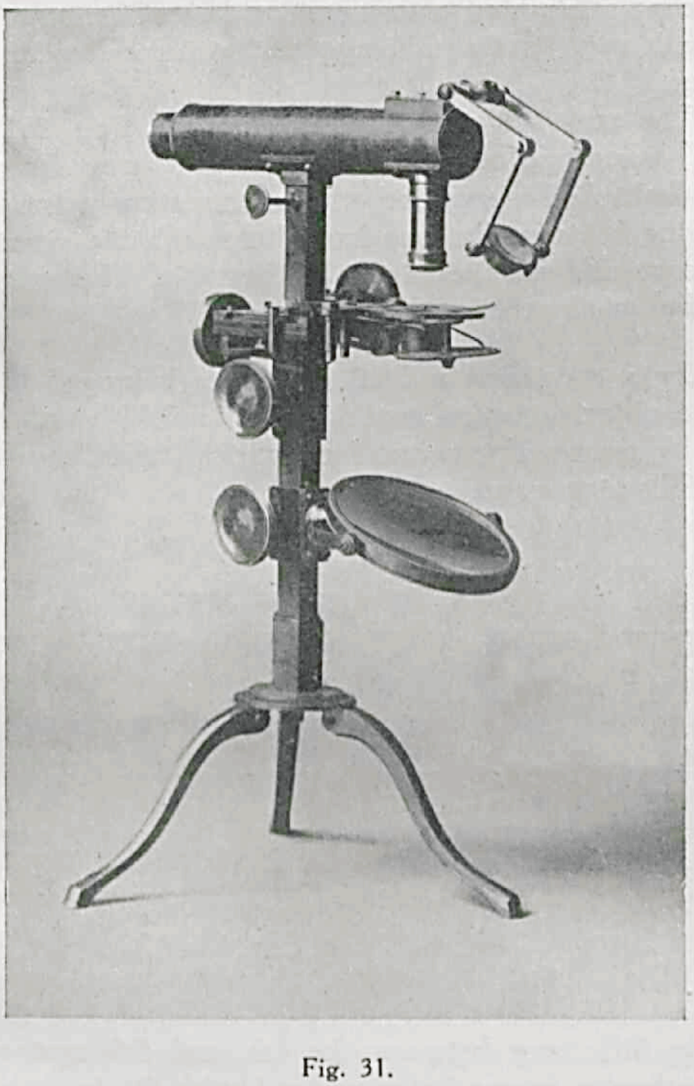

Fig. 31.

to the microscope tube, and one of the objectives is fitted with a Lieberkuehn mirror.

There are three different camera lucida with this microscope:

1). The small *Sömmering* mirror (Cp. Harting III pg. 435

resp. pl. VII fig. 19), i.e. a mirror smaller than the pupil of the eye; it was placed at an inclination of 45° behind the eyepiece. Looking straight down it one could see via the small mirror into the microscope, and along its edge on the table beyond.

2). A glass plate a few mm thick, which was placed like the little mirror at an inclination of 45° behind the eyepiece (Cp. Harting III pg. 435). By this means one could see the table through the plate and, by the reflection of the front surface, into the microscope. This kind of camera lucida could, naturally, only be used with very strongly illuminated objects and with low magnifications.

3. The camera lucida of *Amici* (Harting I pg. 257 resp. pl. V fig. 85) consisting of a small perforated mirror likewise slanting at 45° behind the eyepiece and an inverting prism underneath. Observing horizontally, one looked through the opening into the microscope and via the mirror at the table. The prism served to erect the image reverted by the mirror.

Originally 5 eyepieces and 10 objectives belonged to the microscope. The objectives numbered from 1 to 8, 10 and 12 could be combined by means of two small cylindrical tubes, numbered 0 and 11 in the following ways:

1°	2°	3°	4°	5°	6°	7°	8°
10	10						
	11	0	0	0	0	0	0
	12	1	1	1	1	4	6
			2	2	2	5	7
				2	3	6	8

The only difference between the 4th and 5th system is that a small Lieberkuehn mirror (also marked with 2) is attached at the lower end of the combination 0, 1, 2.

With the combinations 1° to 5° the thickness of the cover glass was of no importance; the 6th required a definite, clearly determined thickness, the 7th could be used without a cover-glass, while with the 8th it was necessary to cover the object with a thin mica plate.

Amici gives the following magnifications for the distance from the eyepiece tot the surface of the table (33 cm):

Eyep. / Obj.	1	2	3	4	5
1°	38				
2°	61				
3°	120				
4°	247	480	636	1039	
6°	348	676	896	1264	4685
7°	305	591	784	1406	4100
8°	585	1137	1507	2263	7881

Unfortunately, of all these optical accessories only tube 0, objective 2 fitted with the Lieberkuehn mirror, and the eyepieces 1, 3, 4 and 5 are left. Although the objective 2 was not meant to be used without one of the others the images obtained by it are exceedingly sharp. Combined with eyepiece No. 1. the magnification is × 80, with No. 3. × 200 and with No. 4. × 320. In all three cases it resolves $^{1}/_{400}$ mm; a value which none of the microscopes described above, compound or simple, can reach with a magnification of 80. With eyepiece No 5., it is not easy to focus sharply.

Of the eyepieces, No 1. is a very long one; it consists of a plano-convex field-lens and ditto eye-glass; the plane surfaces of both are turned towards the eye. No 3. is an Huyghenian eyepiece also fitted with two plano-convex lenses. No 4. is composed of two plano-convex lenses, one immediately on top of the other, whereas No 5. consists of one single almost spherical lens. *Amici* remarks that this last one is practically never used. The eyepieces 1 and 3 are provided with spider-lines, used for measurements with the stage-micrometers. The combination 6, 7, 8 was not originally included among the accessories of the instrument in the price paid for it but were presented by *Amici* as an expression of his high esteem for *Prof. G. Moll* at *Utrecht*. The microscope was originally provided with an arrangement by means of which it could be used as a vertical and as a simple microscope as well. This arrangement is now however missing.

O. Microscopes of Chevalier.

Three members of the *Chevalier* family in Paris, namely, *Vincent, Charles* and *Arthur,* won widespread fame in the 19th cent. as constructors of achromatic microscopes. It was *Charles Chevalier,* apparently, who first thought of making stronger objectives by combining a number of small lenses, each of which had been corrected separately. (± 1824).

O. 1. *Microscope of Chevalier.*

This instrument dating from 1837, bears the inscription:

"Microscope Achromatique de
Charles Chevalier,
Ingenieur Opticien Breveté,
Palais Royal 163, Paris."

It is kept in a mahogany case which serves as its foot when in use (fig. 32). Along the square stand, which carries the microscope, the illuminating mirror and the stage can be slid. The illuminating mirror is concave on one side and has a plane surface of a smaller diameter on the other. There are two interchangeable stages with the instrument: a fixed one and a mechanical one after the system of *Tyrrell,* (cp. Harting III pg. 397 and pl. IX fig. 11). Under the table is a cone which can be rotated out of the optical axis and carrying a wheel with 6 diaphragms. The microscope tube itself can be pushed in or drawn out. The optical accessories accompanying the instrument are 4 objectives and two Huyghenian eyepieces. Each objective consists of a system of three small corrected lenses.

With tube pushed in, the magnifications and the resolv. powers are:

Obj.	Magnification.		Resolv. p.
	Eyep. 1	Eyep. 2	
1	× 55	× 100	1/200 mm
2	120	210	1/400 „ „
3	280	540	1/600 „ „
4	500	1000	?

The resolving power of objective No 4. could not be tested by means of the Grayson rulings because its focussing required the distance between object and objective to be smaller than the thickness of the cover-glass of the testplate.

There are also two doublets with the instrument, by means of which it can be used as a simple microscope, in which condition it is practically the same as the model described under D. 4 and illustrated in fig. 11. (Magn. and resolv. p. $\times$ 22 and $^1/_{100}$ mm and $\times$ 37 and $^1/_{200}$ mm resp.).

Further accessories are:

condensing lens for the illumination of opaque objects

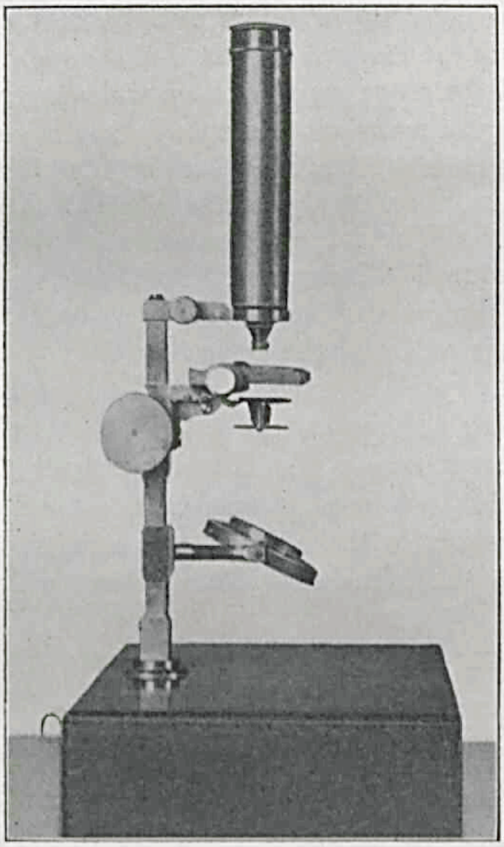

Fig. 32.

compressorium of *Schiek* (cp. Harting III pg. 388 and pl. VII fig. 7.)

object-micrometer divided into $^1/_{100}$ mm.

various implements for dissecting purposes

camera lucida after *Chevalier* bearing the inscription *"Nachet à Paris"*. The arrangement of this camera lucida is about the same as of that described under No. 3, in N. 1. only the reversing prisma is placed differently, in connection with the vertical position of the microscope. (Cp. v. Heurck pg. 90).

O. 2. *Large microscope of Chevalier.*

This instrument was purchased by *Harting* in 1869. It bears the inscription:

"Arthur Chevalier
Palais Royal 158
Paris."

The construction is very much the same as that of a modern microscope. The foot has the horse-shoe shape and the instrument is jointed on to it, so that it can be made to incline. The microscope is carried by an arm fixed sideways on to the stage. The fine focussing is obtained by screwing it up or down over a short distance along that arm. It differs from the modern type in that it can be revolved, together with the arm and the stage round the optical axis, a possibility of motion shown in a great many instruments dating from the middle of the 19th century; it was meant to facilitate the modification of the direction of the light-rays relatively to the object while working with a slanting illumination. The stage is a mechanical one after the (slightly altered) *Tyrrell* system. Underneath this stage a short tube adjustable by rack and pinion, carries at its lower end a diaphragm wheel with four apertures, while at the same time its upper end can be covered by perforated caps. The microscope tube is extensible. The optical parts accompanying the instrument are 6 objectives and 3 eyepieces. In the latter is a groove in which a micrometer can be fitted. The following magnifications were measured by *Harting*. The resolving powers here given are for the weakest eye-piece and with tube pushed in. The values for the other eye-pieces do not differ materially from these:

Eyep.	1	2	3	1	2	3	Resolv. power
Obj.	Tube in			Tube out			
1	×33	×49	×83	×47	×71	×120	1/200 mm
2	44	60	99	53	71	115	1/400 ,, ,,
3	78	120	177	102	148	217	1/600 ,, ,,
5	254	323	526	326	434	676	1/1200 ,, ,,
8	400	568	864	543	771	1173	1/1400 ,, ,,
9	425	604	918	577	820	1247	1/1600 ,, ,,

Further accessories are:

drawing prism of *Chevalier*
eyepiece micrometer divided in 0.1 mm
object micrometer divided in 0.01 mm.

P. Microscopes of Lerebours and Secretan.

In the middle of the 19th century the firm *Lerebours,* later on *Lerebours et Secretan,* became very well known for their construction of achromatic microscopes.

P. 1. Horizontal microscope of Lerebours et Secretan.

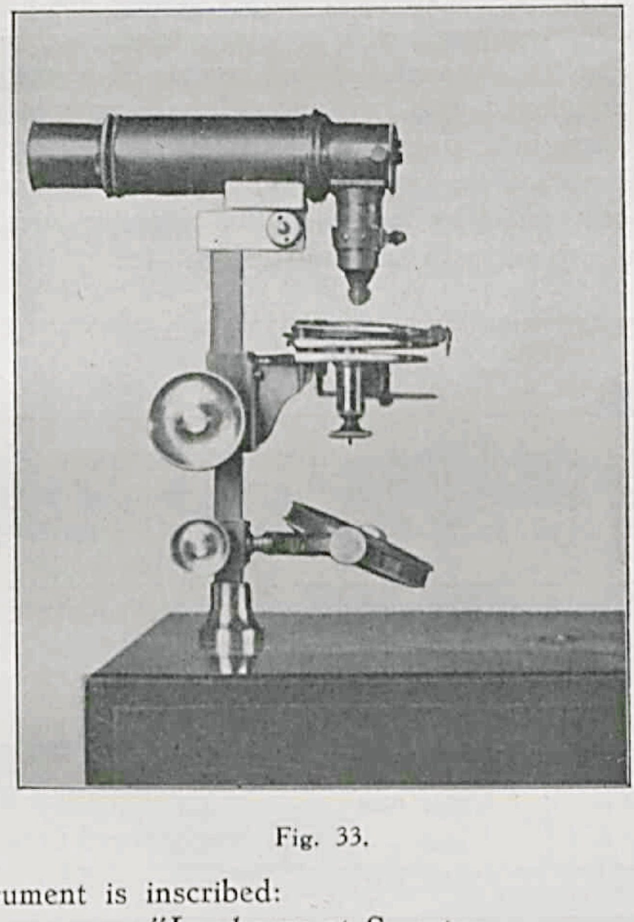

Fig. 33.

This instrument is inscribed:

"Lerebours et Secretan,
à Paris."

It is screwed on its own box when in use and the stage and the illuminating-mirror can slide along the stand by means of rack and pinion (fig. 33). An extra arrangement for fine focussing is attached to the stage. The latter consists, namely, of two plates, one over the other, of which the top one can be screwed up and down relatively to the lower one. On this stage can be fitted another, with centring adjustment *(Oberhäuser* system, Harting III pg. 376 and pl. IX fig. 12). Under the stage is a diaphragm wheel with four apertures.

The microscope itself is hinged on to the stand and can be used in two ways:

a) as a horizontal microscope, with the aid of a prism and objective fitted together in a mount, attachable to the instrument by a bayonet socket;

b) as a vertical microscope, with the aid of a mounted objective, without a prism, but likewise attachable by a bayonet fitting.

The microscope tube is extensible. There are three objectives with this instrument. No. 1. is a single achromatic lens. No. 2. and No. 3. each consist of a system of three lenses. There are also 4 eyepieces of which No 2. is equipped with a point micrometer. In order, namely, to determine the distance between a pair of points in the image, this eye-piece is fitted with two minute sharp-pointed shafts, which, by screwing them in or out, can be adjusted in such a way that their ends coincide with these points. The required distance can then be measured subsequently by means of the objective-micrometer.

The magnifications with tube pushed in are:

Eyep. / Obj.	1	2	3	4
1	× 60	× 90	× 135	× 190
2	200	300	440	630
3	350	520	780	1100

The edges of the images are hazy.

The resolving powers are:

Obj. 1	$^1/_{200}$ mm
2	$^1/_{600}$ „ „ (with eye-piece 3 : $^1/_{800}$ mm).
3	$^1/_{800}$ „ „

Further accessories with the instrument are:

small trough for liquids

camera lucida of *Nachet*

(Cp. Harting III pg. 346 and pl. IX fig. 3').

P. 2. Microscope of Secretan.

This instrument bears the inscription:

"Lerebours et Secretan à Paris."

The box, however, belonging to it is inscribed: *"Secretan, successeur"*.

The microscope is of the same design as the "drum" microscope reintroduced by *Oberhäuser* about the year 1835. The base has the form of a drum and the illuminating mirror is fitted inside it. The stage is mounted on top of it and under the stage is a wheel of diaphragms with 5 apertures. Above the stage is a fixed tube, the inside of which is threaded with a very coarsely worked pitch with a high speed and in which the microscope tube, by turning it on its axis, can be screwed up and down. The fixed tube carries a condensing lens for opaque objects. The mounting of the objective is very remarkable. The mount consists of two cones, one inside the other, to each of which the various small lenses can be screwed on. This device made combinations of the lenses possible in which they are not screwed one right against the other but remain apart at fixed distances one above the other. According to *Harting* three lenses belonged to this instrument (Harting III pg. 198 and pl. V fig. 8'), which could be combined in the following way:

a. on the lower cone 1, 2, 3.
b. ,, ,, ,, ,, 2, 3 on the upper cone 1.
c. ,, ,, ,, ,, 2, ,, ,, ,, ,, 1.
d. ,, ,, ,, ,, 1.

Unfortunately lens 1 is missing, and it was therefore impossible to measure any of these combinations.

When the instrument is used in the ordinary way the magnifications and resolving powers are:

Obj.	Magnification		Resolv. p.
	Eyep. 1	Eyep. 2	
3	× 40	× 70	$^1/_{100}$ mm
2	92	160	$^1/_{200}$,, ,,
2+3	130	225	$^1/_{400}$,, ,,

Q. Microscopes of Oberhäuser-Hartnack.

A very great improvement in the construction of microscopes is due to G. *Oberhäuser* in Paris, (who was afterwards succeeded by his nephew *E. Hartnack,* at first also in Paris, later after 1870, in Potsdam). In 1835 *Oberhäuser* had already succesfully reintroduced the so-called "drum-microscope". In 1848 however, he designed and made the first horse-shoe microscope, a form which has held its own up to now.

Q. 1. Pancratic drum microscope of Oberhäuser.

Though it does not bear his signature, this instrument is very probably made by *Oberhäuser*. The construction answers completely to the description by

Harting III, pg. 187—189 resp. pl. VI fig. 2.
Petri pg. 179—180.

As the name indicates, the base is drum-shaped; an opening is made in it to allow the light to fall on to the illuminating-mirror inside the drum, (fig. 34). The stage is mounted on it in such a way that it can be turned, together with the microscope itself, round the optical axis. Underneath the stage is a slide in which a short tube can be moved up and down with the aid of a lever. In this tube the following articles are made to fit:

a. various diaphragms
b. a mounted nicol
c. an apparatus after *Nachet* for slanting illumination (Cp. Harting III pg. 352, pl. VI fig. 9.)
d. a small tube into which one of the objectives can be screwed so as to serve as a condensing-lens.

The coarse adjustment is obtained by rack and pinion; the subsequent fine adjustment by means of a screw.

The microscope itself is very remarkable. Inside the tube which carries the objective fits a second sliding- or draw-tube, which can be fitted with an objective also. The same instrument can be used, therefore, as an erecting and as a pancratic microscope. The second objective furnishes, namely, an inverted image of the image, due to the first objective, which is itself already inverted. In this way, the image is not only put right again, but the arrangement admits of a continuous alteration of the magnifications, too, by changing the distance between the two objectives. (Cp. Harting III pg. 262).

The following accessories belong to the instrument:

1 simple objective
6 objectives, each consisting of three lenses
one objective, Nachet No 7.
three eyepieces, numbered 1, 2, 3
one eyepiece of the same power as No. 1 but provided with a micrometer with divisions of 0.01 mm.

The magnifying and resolving-powers for normal use of the microscope are:

Eyep. / Obj.	Magn. power			Resolv. power
	1	2	3	
single	× 105	× 125	× 225	$^1/_{400}$ mm
triplet 1	130	155	270	$^1/_{600}$ „ „
„ 2	155	185	320	$^1/_{600}$ „ „
„ 3	220	265	455	$^1/_{1000}$ „ „
„ 4	230	275	475	$^1/_{1000}$ „ „
„ 5	320	385	660	$^1/_{1200}$ „ „
„ 6	560	670	1150	$^1/_{1400}$ „ „
Nachet 7	660	790	1360	$^1/_{1400}$ „ „

The resolving power turns out to depend on the objectives only; the eyepieces have no influence. The images are slightly distorted, even in the case of smaller magnifications.

Still further accessories are:

mounted analysing calcite prism to be fitted on the eyepiece
mounted achromatic calcite prism
camera lucida of *Nachet*
various dissecting implements
3 object micrometers signed
"Charles Chevalier. Palais Royal a Paris."

One of them is divided in squares of $^1/_{100}$ mm, another in

squares of $^1/_{10}$ mm, and the third is a scale of 2 mm, divided in 200 parts.
mechanical stage after *Tyrrell.*

Q. 2. Horse-shoe microscope of Oberhäuser.

This instrument is signed *"Georges Oberhäuser"*. In the microscope-tube the number *1550* is engraved. (cp. Harting III pg. 290). In 1848 the Physical Laboratory bought it for *f* 350. Later on it was

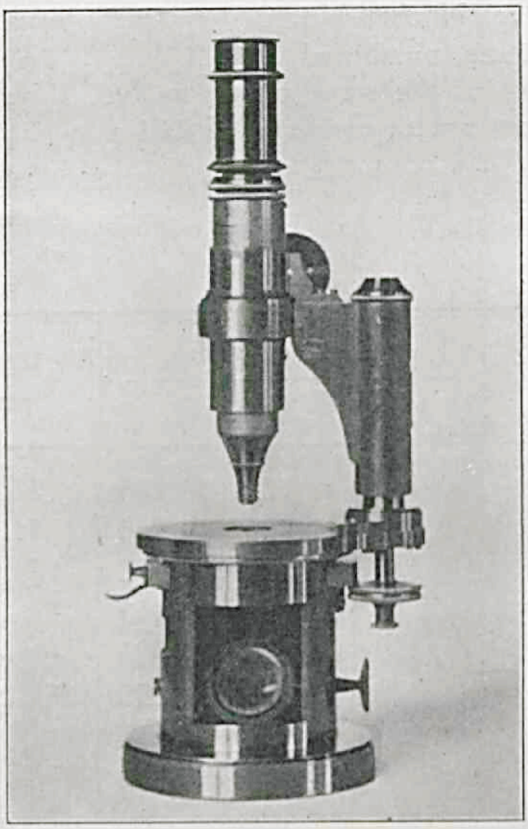

Fig. 34.

given to *Harting* in loan. It was evidently he who ordered it for the laboratory, for the case accompanying it contains a letter to *Harting* written by *Oberhäser* and dated Sept. 21st 1848.

The original illuminating mirror and the diaphragm apparatus are removed and replaced by an illuminating arrangement of *Harting's* own invention. The mirror is fixed to a set of hinges which admits of its position out of the optical axis for slanting illumination. The illuminating-set itself can be slid by rack and pinion along the divisions of a scale so that its displacements can be measured. It consists of a plano-convex condensing lens of focal lenght 1,5 cm. and under it a square diaphragm of which the size can be varied gradually. (Diaphragm of *Dollond*. Cp. Harting III pg. 363 and pl. VII fig. 15 and 16). The whole arrangement can be moved on a slide-rest out of the optical axis and can also be inclined in such a way that the light can always pass at right angles through the condenser. Another slide-rest is attached underneath to the bottom of the stage, which can be made to carry small tubes fitted with diaphragms. For a description of this illuminating arrangement see:

Harting I, pg. 285—287.
Petri, pg. 220—221.

The coarse adjustment is obtained by moving the microscope tube up or down by hand, the fine focussing, however, by means of a micrometer-screw in the head of which is a scale divided into hundred parts (one revolution of the screw = 0.492 mm). The microscope-tube is extensible and the extensible part is also provided with a scale. The tube, together with the stage, of this instrument can turn round the optical axis.

Of all the original accessories, only two small achromatic lenses and 5 eyepieces are left. Of the latter those numbered 1 and 2 have equal powers, but 2 is fitted with a micrometer with a scale division of 0.01 mm.

With tube pushed in, the magnifications and resolving powers are:

Eyep. / Obj.	magnification				resolv. power
	1, 2	3	4	5	
1	× 20	× 26	× 47	× 56	$^1/_{200}$ mm
2	50	68	120	140	$^1/_{200}$ „ „
1 + 2	70	95	170	200	$^1/_{400}$ „ „

With the instrument is a very extensive table, drawn up by *Harting*, of magnifications obtainable with this microscope, with the aid of many objectives and eyepieces belonging to other instruments.

Q. 3. Microscope of Hartnack.

This instrument bears the inscription:

"E. Hartnack et Cie
Place Dauphine 21
Paris."

It is very beautifully made and of very solid construction. Its arrangement, as well as its optical qualities, nearly reach the high standard of modern microscopes. It is mounted on a horse-shoe base by a joint, so that it can incline at any angle desired. To the bottom of the stage is attached a heavy brass strip, in the slot of which the illuminating mirror and the plano-convex condensing lens can slide up and down. The mirror admits of a sideways motion, too, to make slanting illumination possible. The condensing lens can be fitted with diaphragms which screen off the centre of the field of vision, (dark-ground illumination). A slide rest, carrying a diaphragm-holder, is attached underneath the stage. The diaphragms belonging to it are separate small caps. This holder can also be fitted with a slide for small blue glasses. The microscope itself, together with the stage can be turned round the optical axis. The coarse focussing is effected by rack and pinion and the finer adjustment by means of a micrometer screw.

There are 6 objectives with the instrument, marked 2, 4, 5, 7, 8 and 9, and one water-immersion, marked 11. The numbers 9 and 11 are fitted with cover-glass correction. There are, moreover, 7 eyepieces: 1, 2, (fitted with a 0,1 mm. micrometer) 3, 4, 5, 5' [1]) and 6. The last one is "holosteric", that is to say, a Huyghenian eyepiece, consisting of a single solid piece of glass with ground surfaces of different curvature on both sides. With the microscope is a table of magnifications, obtainable with objectives 2, 4, 5, 7 and 9; and with eyepieces 1, 2, 3, 4, 5, provided by the maker himself. Objective 8, the immersion 11, and the eyepieces 5' and 6 were evidently bought and added later.

To the microscope belongs, further, a very lage plano-convex illuminating lens mounted on a separate foot.

With tube pushed in, the magnification and resolving powers are:

	Magnification							Resolv. power (mm)						
Eyep / Obj.	1	2	3	4	5	5'	6	1	2	3	4	5	5'	
2	18	23	31	48	57	70	82	$\frac{1}{100}$	$\frac{1}{200}$	$\frac{1}{200}$	$\frac{1}{200}$	$\frac{1}{200}$	$\frac{1}{200}$	$\frac{1}{200}$
4	40	50	70	105	125	155	180	$\frac{1}{200}$	$\frac{1}{400}$	$\frac{1}{600}$	$\frac{1}{800}$	$\frac{1}{800}$	$\frac{1}{800}$	$\frac{1}{800}$
5	80	100	140	210	250	310	360	$\frac{1}{600}$	$\frac{1}{800}$	$\frac{1}{1000}$	$\frac{1}{1200}$	$\frac{1}{1200}$	$\frac{1}{1200}$	$\frac{1}{1200}$
7	135	170	230	360	425	520	610	$\frac{1}{1000}$	$\frac{1}{1200}$	$\frac{1}{1400}$	$\frac{1}{1400}$	$\frac{1}{1400}$	$\frac{1}{1400}$	$\frac{1}{1400}$
8	215	275	360	575	680	840	980	$\frac{1}{1200}$	$\frac{1}{1400}$	$\frac{1}{1600}$	$\frac{1}{1600}$	$\frac{1}{1600}$	$\frac{1}{1600}$	$\frac{1}{1600}$
9	300	380	515	665	950	1150	1350	$\frac{1}{1000}$	$\frac{1}{1000}$	$\frac{1}{1000}$	$\frac{1}{1000}$	$\frac{1}{1000}$	$\frac{1}{1000}$	$\frac{1}{1000}$
11	340	430	580	900	1150	1300	1550	$\frac{1}{1800}$	$\frac{1}{1800}$	$\frac{1}{1800}$	$\frac{1}{1800}$	$\frac{1}{1800}$	$\frac{1}{1800}$	$\frac{1}{1600}$

[1]) Accentuation by the writer.

The very large magnifications with objective 9 are evidently obtained at the cost of the resolving powers.

As regards the latter, the instrument can certainly compete with many modern microscopes. One of the modern instruments, constructed by one of the best factories, gave, with the same magnifications, the same values for the resolving powers. And for the smaller magnifications the maximum resolution obtainable without the help of some special device, is reached.

R. Microscopes of Nachet.

The firm, *Nachet* in Paris, which still exists, became very well-known in the 19th century for its microscopes. The Utrecht collection possesses only three smaller instruments of this make.

R. 1. Small drum microscope of Nachet.

This bears the inscription:

"Nachet, Opticien
Rue des Grands Augustins 4
Paris."

Its construction is very simple. The hollow illuminating mirror is fitted in the interior of the drum-shaped base. Underneath the stage is a revolving diaphragm-wheel with four apertures, and above the stage there is a separate plate which can be screwed up and down, a contrivance by which the fine focussing is obtained. The coarse adjustment is obtained by moving the microscope tube up or down by hand. A plano-convex illuminating lens is hinged on to the body-tube in which the microscope can be made to slide. The microscope tube itself is extensible.

Its accessories are, at present, only one eyepiece and three objectives; two of the latter consist of two, and the third of three small achromatic lenses.

	Magnification		Resolv. p.
	Tube drawn in	Tube drawn out	
Objective in 2 parts	× 110	× 150	1/200 mm
„ „ „ „	200	275	1/400 „ „
Objective in 3 parts	400	550	1/800 „ „

R. 2. Small drum microscope of Nachet.

Its construction is exactly the same as the one described under R. 1.

Its accessories are two eyepieces, marked 1 and 2, and further one objective consisting of two systems of lenses about 1.5 cm apart.

	Magnification		Resolv. p.
	Tube drawn in	Tube drawn out	
Eye-piece 1.	× 60	× 85	1/400 mm
Eye-piece 2.	90	125	1/400 „ „

R. 3. Small microscope of Nachet.

This instrument bears the inscription:

"Nachet et fils
Rue St. Severin 17
Paris."

Although, like the other instruments of *Nachet*, it is mounted on a round foot, the drum is dispensed with. This made it possible to fit the mirror so as to admit of motion in all directions. Under the stage is the diaphragm-wheel with three apertures. The coarse adjustment is again effected by hand; the fine one, however, by screwing the microscope up and down. An illuminating lens belongs also to the instrument. The optical parts are: three objectives marked 1, 3 and 5 and two eyepieces 1 and 3. Objective No. 1 consists, like the one under R. 1. of two lenses 1.5 cm apart. Numbers 3 and 5 consist of three small lenses screwed one immediately on top of the other. Eyepiece No. 3 contains a micrometer in 0.1 mm.

The various magnifications and resolving powers are as follows:

Eyep. / Obj.	Magnification				Resolv. p.
	Tube in		Tube out		
	1	3	1	3	
1	× 55	× 130	× 80	× 180	1/400 mm
3	165	380	230	540	1/600–1/800 mm
5	240	560	345	800	1/1000 mm

S. Miscellaneous.

S. 1. Microscope of Schokking. [1])

This instrument is signed:

*"J. A. J. Schokking
Spui 18, Amsterdam."*

It is constructed as follows: on a rectangular foot are mounted two brass pillars which carry the stage and the microscope. The latter is attached in such a way as to admit of every requisite inclination. Under the stage are the mirror and diaphragm wheel with four apertures. Above the stage a harp-shaped object-clamp can be slid up and down with a sleeve along the tube carrying the microscope. The coarse focussing is done by hand, the fine one by means of a screw. With the instrument are one objective, consisting of two small lenses, and one eyepiece. The magnification, with tube pushed in, is $\times$ 250, with tube drawn out, $\times$ 320; the resolving powers in both cases are $^{1}/_{400}$ mm.

S. 2. Compound microscope.

This instrument, too, admits of every requisite inclination between two pillars which here, however, are mounted on a horse-shoe foot. The stage, under which a diaphragm-wheel with four apertures is fitted, admits of motion in all directions, by means of a lever [2]) (fig. 35). The prelimanary focussing is effected by rack and pinion; the final one by means of a screw, which moves the objective up or down with the aid of a lever system. A condensing lens it attached to the stage. The optical outfit accompanying the instrument consists of 3 objectives and 2 eyepieces. The objectives are numbered 1, 3 and 4. No 1. is a system of 2 achromatic lenses No. 3 and 4 are systems of 3 small achromatic lenses.

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[1]) *Schokking*, formerly living in Binnen Wieringerstraat, Amsterdam, lived in 1875 at Spui 18, also Amsterdam. The number 18 was altered in 1884 to number 32. The microscope must therefore be dated sometime between 1875 and 1884.

[2]) More or less as illustrated in Harting III pl. VIII fig. 15.

Eyepiece / Obj	Magnification 1	Magnification 2	Resolv p.
1	× 95	× 190	$^1/_{460}$ mm
2	220	440	$^1/_{800}$ „ „
3	320	640	$^1/_{800}$—$^1/_{1000}$ mm

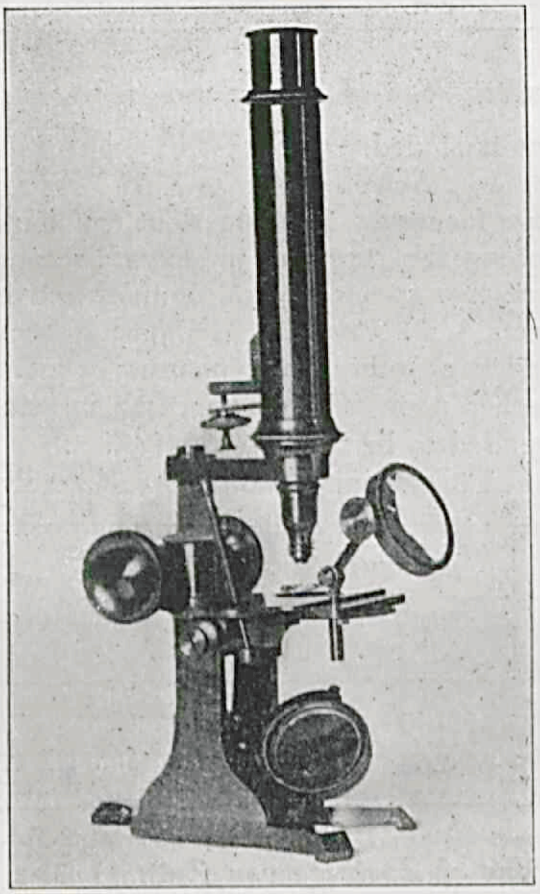

Fig. 35.

S. 3. Compound microscope.

This instrument is fastened by means of a joint to a tripod of a peculiar shape. [1]) The stage is a mechanical one after the *Tyrrel* system (slightly altered) on top of which a revolving stage is fitted. The

[1]) The tripod is exactly the same as the one in Petri pg. 216 where a microscope of *Mawson and Swan* is illustrated.

coarse focussing is again done by rack and pinion, the final adjustment by moving the objective up or down by means of a screw. The optical parts with the instrument are of *Nachet's* make and consist of two objectives, and one eyepiece. The two objectives are Nachet No 2 and No 5. The latter is fitted with a correction for cover-glass thickness. The magnifications and resolving powers are:

Obj.	Magnification	Res. p.
2	× 180	$^1/_{800}$ mm
5	440	$^1/_{1200}$ „ „

S. 4. Drum microscope of Schiek.

This instrument is signed:

"Schiek in Berlin 155".

Here the course focussing is again done by hand; the fine one however, by screwing the stage up or down. Accompanying the instrument there are two eyepieces and four objective lenses marked 1—4. Only the sets 1, 2, 3 and 2, 3, 4 give images of fairly good quality. The images of other combinations or of the lenses used separately, are rather poor. These two combinations were evidently the only ones intended to be used.

With tube pushed in the magnifications and resolving powers are:

	Magnification		Resolv. p.
Obj. \ Eyep.	1	2	
1 + 2 + 3	× 140	× 280	$^1/_{400}$—$^1/_{600}$ mm
2 + 3 + 4	260	520	$^1/_{800}$—$^1/_{1000}$ „ „

S. 5. Microscope of Zaalberg van Zelst. [1])

This instrument bears the signature:

"Zaalberg van Zelst
Amsterdam."

It was made by him especially for a prize competition at Leiden where it won the gold medal. Hence the engraving in the foot: *Gold medal. Leiden. 1865.*

The stand is connected to the foot by a joint and carries, under

[1]) *Zaalberg van Zelst* was established as an instrument maker at Singel, Amsterdam at about 1860. He subsequently carried on the same profession at The Hague.

the stage, the illuminating mirror, a condensing lens, a piece of blue glass and a continuously variable diaphragm, system *Dollond* (cp. Q. 2.). The condenser is fitted with a diaphragm for dark-ground illumination and both condenser and blue glass can be turned out of the optical axis. On the stage a movable slide serves to place the object glasses against it. The coarse focussing is done by hand, the fine one by means of a screw. Another illuminating lens of dark blue glass is attached to the microscope. Accompanying the instrument is a small case made in imitation of a miniature prayer-book and containing four objectives and three eyepieves. The objectives are numbered 0, 1, 3 and 5. The following magnifications and resolving powers were measured:

	Magnification			
Eyep. / Obj.	1	2	3	Resolv. p.
0	× 15	× 21	30	$^1/_{100}$ mm
1	37	52	75	$^1/_{200}$ „ „
3	100	140	200	$^1/_{600}$ „ „
5	150	210	300	$^1/_{800}$ „ „

There is a table of magnifications on a paper, pasted in the lid. These values are however, from 50% to 75% too high.

S. 6. Miniature microscope.

The height of this diminutive drum-microscope measures only 8cm. On the lid of the case there is a groove in which the instrument can be set up. Its magnification is × 45 and the resolving power $^1/_{100}$ mm. The images are distorted and still slightly chromatic.

T. Dissecting microscopes.

For dissecting microscopes, use is made of low power simple or compound microscopes, but compound microscopes with negative eyepieces, because the images of these microscopes are not inverted.

T. 1. Dissecting microscope of Zeiss.

This instrument bears the signature:

"Carl Zeiss
Jena."

On a heavy foot a tube is mounted to which the large stage is attached. The latter is fitted with hand-rests. A triangular rod can be slid up and down in the tube by rack and pinion. This rod carries the small microscope. Under the stage the illuminating mirror is jointed so as to admit of a motion in all directions. The eyepiece is a very strong, small negative lens. The objective consists of three achromatic lenses which can be used either separately or combined in a set of two, or all three together. The magnifications and resolving powers obtained are:

	Magn.	Resolv. p.
one lens	× 35	$1/_{200}$ mm
two lenses	50	$1/_{400}$,, ,,
three lenses	100	$1/_{600}$,, ,,

For a description and illustration of this instrument see Petri, pg. 98.

CHAPTER V.

Projection-microscopes.

U. Projection-microscopes provided with a solar mirror.

Since the higher the magnification, the stronger the illumination of the object must be in order to obtain images of the right intensity, and particularly so when the image is projected on a screen, it is only natural that during the 18th century one availed oneself for micro-projection of the only strong source of light then at one's disposal, namely the sun. As however the direction observer-sun changes continually, it was necessary to fit the microscope with an adjustable mirror, which could be turned so as to follow the motion of the sun. As a rule, the solar mirrors could move in two independent ways, namely round the optical axis of the microscope and round an axis at right angles to the first. The latter rotation, therefore, varies the inclination of the mirror. By means of these two rotations one could always contrive to throw the light of the sun through the illuminating tube.

U. 1. Solar microscope.

The inclination of the solar mirror of this very primitive instrument is varied with the aid of a nut which can turn in the plate carrying the mirror and the microscope; and through the nut passes a screw, which is simply bent round, and which is attached to the mirror by a joint. (Fig. 36). The motion round the optical axis is effected by turning the instrument wholesale round it. The projecting lens is screwed on to the front end of the microscope tube, while the further end is fitted with a condensing lens. The object is held firmly, as in the case of the screw barrel microscopes, between two small brass plates; these are pushed by a spring against a ring screwn round the microscope tube. By screwing this ring backwards or forwards, the object moves relatively to the projecting lens and this is, therefore, the way, focussing is effected. With the instrument are 4 small projecting lenses. Considering the rather poor workmanship of the mechanical parts these lenses are very satisfactory. The magnifications (for 25 cm distance) and the resolving powers are namely:

Lens	Magnification	Resolv. p.
1	× 55	$^1/_{200}$ mm
2	34	$^1/_{100}$ „ „
3	25	$^1/_{100}$ „ „
4	21	—

U. 2. Solar microscope.

This instrument belonged originally to the foundation *"van Renswoude"* and is therefore probably the work of one of its wards. Its arrangement is very much the same as that of U. 1, only the inclination is varied here by a straight screw of which the motion is transferred to the mirror by means of a lever system.

With the instrument are 2 projection lenses with magnifications of × 7½ and × 17. The latter lens is able already to resolve $^1/_{100}$ mm.

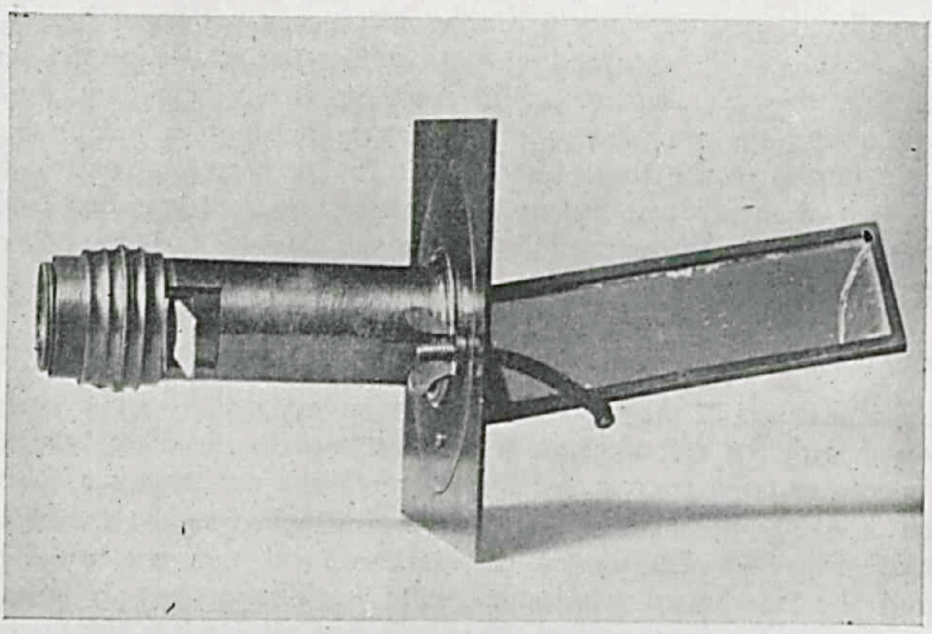

Fig. 36.

U. 3. Solar microscope.

Of this instrument, which is contained in a little mahogany chest with two drawers, the solar mirror is missing. The arrangement agrees completely with the one described and illustrated in Adams pg. 113—115, resp. pl. VI.

To the front end of the microscope tube, which itself is fitted with two condensing lenses about 11 cm apart, a narrow tube is attached which contains the *Hartsoeker-Wilson* object-carrier. Over this tube another can move by rack and pinion. In the front end of the latter a slide with six different projection lenses can move to and fro.

Lens	Magnification	Resolv. p.
1	× 74	$^1/_{200}$ mm
2	54	$^1/_{100}$ „ „
3	39	$^1/_{100}$ „ „
4	21	$^1/_{100}$ „ „
5	16	$^1/_{100}$ „ „
6	11	—

U. 4. Screw-barrel microscope with solar mirror.

This instrument can be used either as a hand-microscope or as a projection-microscope. As a hand-microscope it is completely similar to the screw-barrel microscopes after *Hartsoeker-Wilson*, described under C. In order to use it as a projection microscope the condensing lens is removed and the microscope is put over the conical end of a tube, containing its own condenser, to which the solar mirror is attached. The microscope is quite complete with object- and lens-holders for opaque objects, little glass tubes etc. Everything is kept in a small box. Its optical outfit consists of

one low power lens in wooden mount (W)

six lenses marked 1 to 6 mounted in brass and provided with brass protection caps

one lens mounted in a Lieberkuehn mirror (L).

Their various magnifications and resolving powers are:

Lens	Magnification	Resolving power	
		hand-microsc.	projection-microsc.
1	× 130	$^1/_{400}$ mm	$^1/_{200}$ mm
2	75	$^1/_{200}$ „ „	$^1/_{200}$ „ „
3	45	$^1/_{200}$ „ „	$^1/_{200}$ „ „
4	32	$^1/_{200}$ „ „	$^1/_{100}$ „ „
5	27	$^1/_{200}$ „ „	$^1/_{100}$ „ „
6	16	$^1/_{100}$ „ „	$^1/_{100}$ „ „
L	37	$^1/_{200}$ „ „	$^1/_{100}$ „ „
W	10	—	—

With the instrument is a case containing various mounted objects and a description of these objects in English, which suggests that the origin of the instrument might be English.

U. 5. Nuremberg Solar microscope.

This instrument like the one described under G. 4, is made almost entirely of wood and cardboard. (fig. 37). The object is pressed tight against the edge of the microscope tube by means of a spring. The focussing is effected by screwing the projection lens in its wooden mounting backwards or forwards. From the description accompanying the instrument we gather that it was constructed by the *"Feld-prediger der hochloeblicher van Kalksteinischen Regiments"*. (Field chaplain to the Kalkstein regiment) *Junker* at Magdeburg. In this description which is dated 1791 *Junker* explains at some length how the microscope can be used as either a solar microscope, as a simple microscope or as a camera obscura.

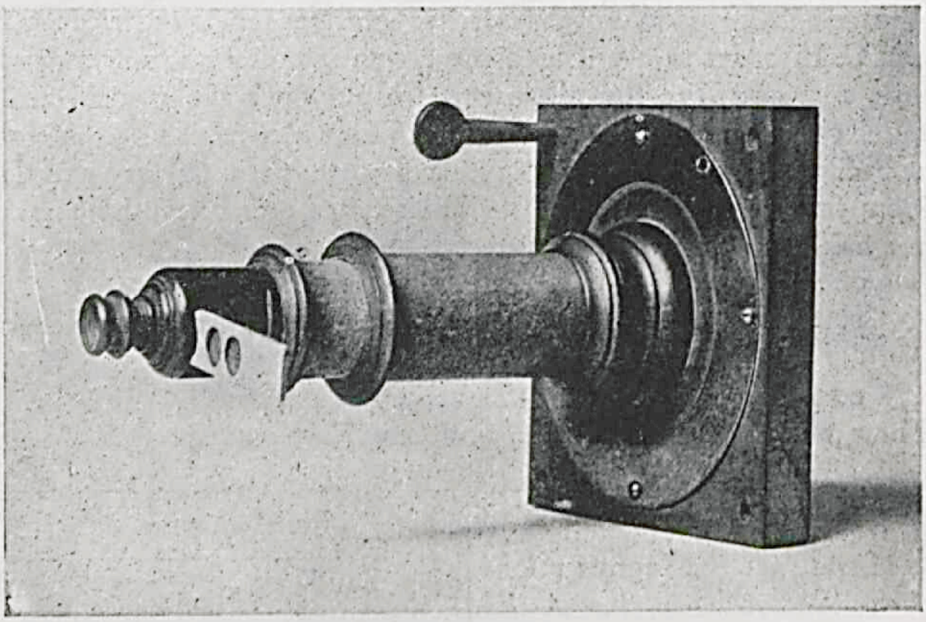

Fig. 37.

As its magnification he gives × 4096, resp. × 32768! Only one lens with magnification 32 and resolving power $^{1}/_{100}$ mm is with the instrument. Junker gave evidently the linear magnifications to the third power ($4096 = 16^3$ and $32768 = 32^3$), as was often done in those days in order to make it seem very strong.

In this same description he goes on to say:

"Dieses ganzes Instrument nun erbiete ich mich den Schulen und „Erziehungsanstalten für 5 Rthr im Golde, andern Liebhabern für 6 „Rthr im Golde besorgen zu lassen, wenn es bei Zeiten bei mir bestellt „und das Geld darauf voraus bezahlt wird weil ich sonst nicht immer

„im Stande bin, den groszen Kostenaufwand, den dieses Unternehmen „veranlasst, zu bestreiten. Wer weiss, dass ein englisches Sonnen-„microscoop 50 bis 100 Thaler kostet, und es gesehen hat. dass ein „solches Instrument, obgleich gans aus Messing gearbeitet, nichts mehr „leistet, als das, was ich anbiete, der wundert sich, wie es moeglich „sey, es um einen so geringen Preis zu verschaffen. Da es mir aber „nicht um Gewinn, sondern um Ausbreitung wohltätiger Erkenntniss „der Werke Gottes zu thun ist, so uebernehme ich freilich manche „damit verbundene Mühe und Arbeit selbst, ohne auf deren Belohnung „zu rechnen. Ich opfere gern meine Nebenstunden auf, und wage an-„sehnliche Kosten, wenn ich nur meinen Zweck, dies interessante und „wohlthätige Instrument in mehrere Hände zu bringen, erreiche. Be-„sonders wünsche ich es in den Schulen und unter dem Mittelstande „bekannter zu machen, weil bis jetzt hieher dergleichen microscopische „Kenntnisse, wegen des Preises der Instrumente, nicht häufig gekom-„men sind. Ich habe oft gehört, dass selbst gebildetere Menschen „Erzählungen von manchen Erscheinungen durch das Sonnenmicros-„coop für blosse Fabeln gehalten haben, weil ihnen dergleichen noch „nicht einmal zu Ohren, geschweige denn vors Auge gekommen war.

„Setzen mich daher mehrere Bestellungen dazu in den Stand, so will „ich von dem etwaigen Ueberschusse mehreren Schulen und unbemit-„telten Familien das Instrument theils schenken, theils um einen noch „wohlfeilern Preis ueberlassen.

„Ich wünsche von Herzen dass meine wohlgemeinte Absicht nicht „ohne Segen sey, und dass Viele durch dieselben in den Stand ge-„setzt werden mögen, Gottes Grösse auch in den kleinsten seiner „Werke näher kennen zu lernen."

Finally the *"Prediger Friesch zu Xanten im Clevischen"* is mentioned in a margin as the agent "für die Holländische Gegende."

The microscope was bequeathed by *Prof. Dr. G. Moll* together with a great many instruments to the Physical Laboratory.

U. 6. Solar microscope of Cuthberson.

This instrument bears the signature: *"J. Cuthberson te Amsterdam"* [1]). It is large and its mechanical parts are of splendid workmanship. The very large solar mirror is fastened to the cone-shaped illumination tube in a very elegant and solid way. Both ends of this

[1]) *Cuthberson* was an English instrument maker; he was established in Amsterdam at about 1780. He became known especially for designing and constructing numerous electrical apparatus. His most famous piece of work is the huge electrical machine made for *M. van Marum* in 1784, which is still to be seen in the hall of *Teyler's Museum* at Haarlem. The Physical Laboratory at Utrecht possesses also a machine made by him; though it is much smaller than the one at Haarlem it exceeds an average human being in height. During the occupation by the French, *Cuthberson* left Holland and settled in London.

illumination tube are fitted with a condensing lens, the wide end with a large low power lens, the narrow end with a small high power one. In order to make the concentration of light on the object possible the latter lens can be moved by rack and pinion. There are two different mounts for this lens, each with its own rack. They are meant to be used with the two different object-holders belonging to the instrument. At the front end of the illumination tube, namely, a rod is attached, likewise capable of rack and pinion motion and carrying a large object-holder to which the wooden slides with rather big objects can be fitted. To this large object-holder a smaller one can be screwed on to hold the usual objects mounted in small bone sliders. To both object-holders there belongs a sharp-pointed shaft with forceps, which by means of a ball and socket joint can move in every direction. The projectionlens, which for focussing can be moved by rack and pinion also, is placed in front of these object-holders. With the instrument are 6 projection lenses with the following magnifications and resolving powers:

Lens	Magnification	Resolv. p.
1	× 120	$^1/_{200}$ mm
2	38	$^1/_{200}$ „ „
3	13	—
4	10	—
5	6	—
6	3½	—

The strongest projecting lens is mounted in such a way that it could not very well be cleaned; its resolving power, here given, is therefore only a lower limit. As a detail characteristic for the period in which the instrument was used it is worth mentioning that one of the objects in the wooden slide is replaced by an ordinary piece of glass bearing the inscription:

"Vreijheid, Gelijkheyd, Broederschap. 1795" [1])

The instrument was bought by the Physical Society at Utrecht, towards the end of the 18th century.

U. 7. Universal solar microscope of Spiering.

This projection-microscope is signed:

"Jan Hendrik Spiering
Amsterdam."

It can be used in 4 different ways. As shown by fig. 38, it can be

---

[1]) Liberty, Equality, Fraternity. 1795.

used for the microprojection of horizontally placed objects. The cone-shaped illumination tube carries at one end an interchangeable condensing lens, and to the same end is attached the solar mirror. The other end fits in a brass box in which a mirror reflects the light, horizontally incident through the illumination tube, in a vertical direction. Underneath the mirror is the object-holder and still lower down a revolving wheel admitting of rack and pinion motion and fitted with four projecting lenses of various powers (resp. magnifications of 4, 5, 9 and 13). After passing through the projecting lens, the light is once more made horizontal by a second mirror of which the inclination can be varied by a screw.

In the foreground are shown the various accessories necessary for other purposes. To the left is the apparatus for the projection of opaque objects. One end of a brass tube is closed by a small pane of ground

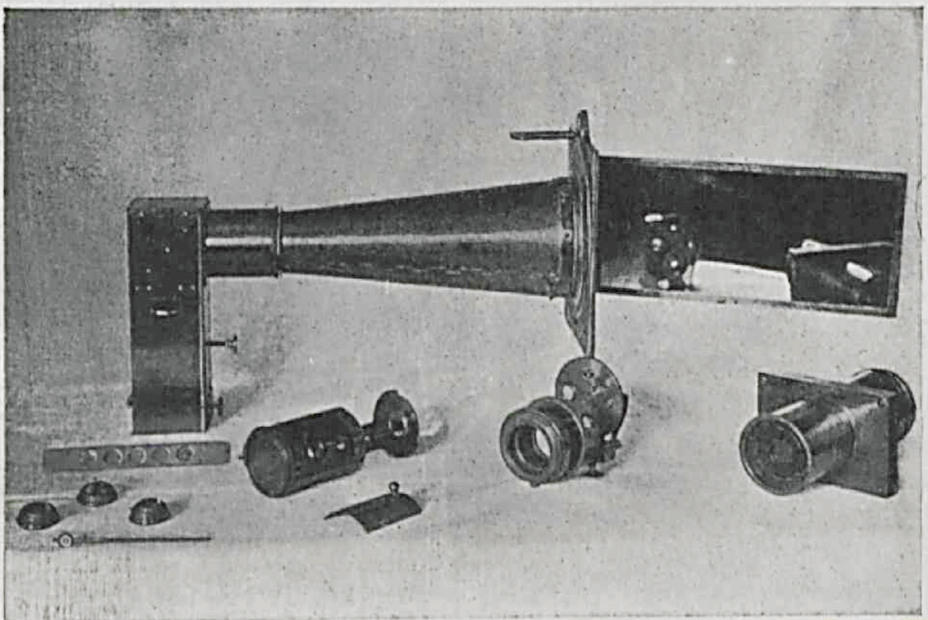

Fig. 38.

glass, the other end by a hollow mirror with a hole in the centre. Close to the focus of the mirror the object is placed, fixed in an ivory cap which is clamped in a brass ring. Behind the hollow mirror another brass ring, carrying the projecting lens is fitted so as to allow of a backward and forward motion. The light falling through the small pane of ground glass is concentrated by the hollow mirror on the opaque object and passes subsequently through the opening in the mirror on to the projecting lens. With this apparatus are 4 projecting lenses with magnifications of 1¼, 2½, 4 and 6.

The arrangement shown in the centre foreground is used in the case of a transparant object, which is clamped between two little brass plates in a slide; in front of it is fitted a wheel with four projecting lenses (magnifications 3, 5, 13 and 17 diameters); the strongest lens resolves $^{1}/_{100}$ mm. The focussing is again effected by rack and pinion. Besides these lenses the four lenses of the apparatus for opaque objects can be used for transparent objects by screwing them on to a ring fitted especially for this purpose in front of the revolver.

Finally, to the right, the arrangement is shown for projecting ordinary lantern plates. For this purpose, the illumination cone is removed wholesale, and the projection apparatus is screwed on, by means of a brass ring, to the plate carrying the solar mirror.

Everthing is contained in a large oak box.

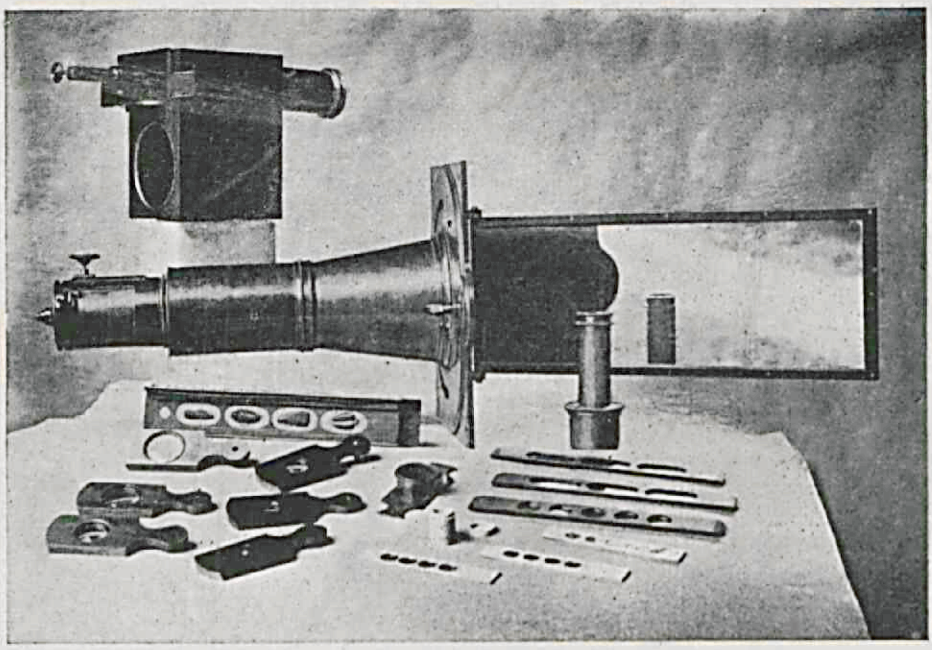

Fig. 39.

U. 8. Large solar microscope of Dollond.

This instrument is signed *"Dollond, London"*. It is a beautifully- and well-made projection-microscope, bought by the Physical Laboratory in 1830 for *f* 504.

It is almost entirely similar to the instrument, described and illustrated in Adams, pages 106—113; resp. plate V (See fig. 39). The optical arrangement is as follows: the illuminating mirror is attached to a heavy brass plate fitted with a condensing lens. This plate carries the illumination-cone at its other side. The projecting-apparatus for either the transparent or the opaque objects can be screwed on to the front part of this illumination tube. The first is a brass tube containing a spring object-holder; a second tube fitted with the projecting-lens at its front end can slide by rack and pinion over the first one. For projecting lenses there are with the instrument:

	Magn. p.	Resolv. p.
A. A slide with 6 small plano-convex lenses (convex side turned to the object):	× 52	$^1/_{200}$ mm
	38	$^1/_{200}$,, ,,
	33	$^1/_{200}$,, ,,
	23	$^1/_{100}$,, ,,
	14	—
	11	
B. Two larger projecting lenses of low power (megaloscope):		—
	8	—
	5	—
C. A doublet lens:	32	$^1/_{400}$ mm

A special slide fitted with a condensing lens and inserted in the spring object-holder immediately in front of the object, belongs to each of the projecting lenses.

The projecting apparatus for opaque objects consists of a rectangular brass box containing a plane mirror which can be inclined in such a way, by means of a screw, that the sunlight is concentrated on the slide with opaque objects, which is clamped in the spring object holder. Opposite this slide two different tubes can be stuck into the box each containing a system of two lenses with variable distance. When at minimum distance the magnifications are resp. × 2 and × 8. With the instrument are, apart from a live box, a great number of slides for all kinds of transparent and opaque objects.

V. Projection microscopes without solar mirror.

When once light sources of sufficient intensity could be obtained so that sunlight could be dispensed with, the construction of projection microscopes without solar mirrors was started. In the second half of the 18th century and the beginning of the 19th, the *Argand* lamp was very popular. This was an oil lamp of which the light intensity was increased by a suitable supply of air. Later on came gaslight, then lime light and finally, electric light.

V. 1. Lantern microscope after Adams.

This extremely beautiful and complete instrument is made by *J. H. Onderdewijngaart Canzius* [1]) at *Delft*. At the *Exhibition of National Industry* held at *Utrecht* in 1808, where the maker was awarded the honorary prize in gold, the microscope was bought by order of *King Louis Napoleon* and subsequently offered by him to the *Theatrum Physicum*. It differs greatly in construction from the instruments described above. (See fig. 40). To a heavy tripod is attached a horizontal pyramidal mahogany box carrying at its one end the projecting system and at the other a plate of ground glass as a projection screen. Immediately in front of the screen a large converging lens can be placed. This lens forms an image of the projecting system in an eye-ring which, fastened to a brass arm, protudes from the microscope.

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[1]) *J. H. Onderdewijngaart Canzius* was born in 1771 at *Delft* of well to do parents. He studied law and physics at *Leiden* and took his law degree in 1790. In 1792 he established himself as a solicitor and notary public but owing to the revolution of 1795 he had to give up these functions. He then founded a workshop for the making of instruments at *Delft*, which under the patronage of the King flourished. But after the departure of His Majesty in 1810, business slackened owing to the general depression. *Canzius* left the country and settled down in *Emmerich* where he was appointed professor of experimental physics and, shortly after, burgomaster. After Germany's liberation from the French occupation he was offered a position at the High Court of Justice in *Berlin* but did not accept it. In 1816 he returned to Holland where he held various important government posts. In 1826 he became Director of the *National Museum of Art and Industry* at *Brussels* but had to resign owing to the separation of Belgium from Holland. He refused a Professorship at the *Université Libre* at *Brussels* because he declined to become naturalized as a Belgian. He returned to *Delft* where he died in 1838. He was not only interested in law and physics but also in theology. For many years he was leader of the congregation *"Christo Sacrum"* at *Delft*. In 1811 he was made honorary doctor of letters at the *University* of *Harderwijk*.

Therefore when the eye looks through this opening all the light that, after passing through the projecting lens, goes to form the image, will be directed by the large lens to the eye, thus making it possible to really observe images of high intensity. Under the mahogany case a tube is attached of square cross section in which by rack and pinion a square rod can move. To this rod the object-holder is attached. There are two different object-holders with this instrument:

a) for opaque objects: a semi-spherical condenser and an inclined hollow mirror concentrate the light on the object, fastened on a wooden slide which can be clamped above the illuminating system.

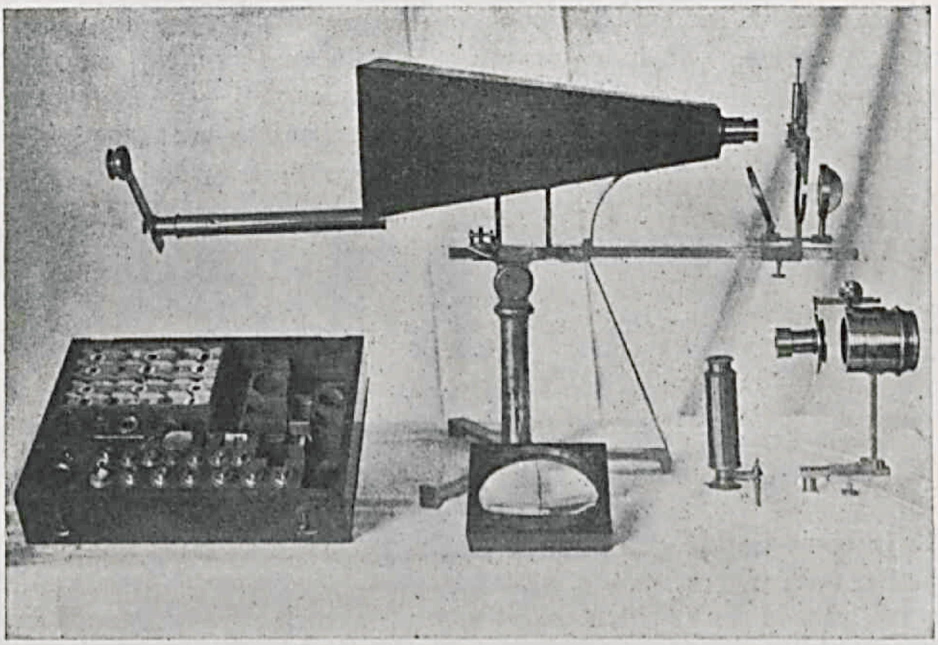

Fig. 40.

b) for transparent objects: a brass tube contains at one end a spring object-holder, at the other end a condenser consisting of two plano-convex lenses. If desired, a ring, adjustable by rack and pinion, can be attached to the object-holder; in this ring the low power projecting objectives c.q. a compound microscope can be fitted.

With the instrument are:

one projecting lens with lieberkuehn: magnification: × 2
two doublets: magnifications: × 9 and × 11½
seven small projecting lenses: magnifications: × 4, 5½, 6, 7½, 9½, 11 and 17.

All magnifications are determined for 25 cm. distance. Since, however, the lantern is 45 cm. long, the above values must, for this instrument, be multiplied by $^9/_5$. Not one of the lenses is capable of resolving only $^1/_{100}$ mm.

The compound microscope mentioned above is fitted with a Lieberkuehn mirror. It has 6 objectives, the lens of number 4 however is missing. The various magnifications and resolving powers are:

Obj.	Magn. p.	Resolv. p.
1	× 130	$^1/_{200}$ mm
2	90	$^1/_{200}$ „ „
3	50	$^1/_{100}$ „ „
5	23	$^1/_{100}$ „ „
6	20	$^1/_{100}$ „ „

With the instrument is a mahogany box containing many objects and accessories. The inventory of the objects is in English, so they were evidently supplied by an English tradesman.

For a detailed description resp. illustration see for instance:

Adams page 64—88, resp. pl. III and pl. IX.
Cat. R.M.S. page 186—187, resp. plate 11.
Clay and Court. page 223—228.

V. 2. Oxyhydrogen microscope.

This microscope is signed:

"J. Newman
Regent Street
London."

It is comparatively heavily built and was purchased about 1830 together with two gas tanks, by the Physical Society at Utrecht. A zinc lantern placed on a little shelf contains the oxyhydrogen burner. (Fig. 41). To the front of the lantern is attached a bent tube fitted with a condenser, consisting of two bi-convex lenses, and with a plane mirror. The end of this tube contains the spring object holder and also the projecting doublet consisting of two plano-convex lenses with their flat surfaces turned towards the object. The focussing is effected by moving this doublet by hand. Its magnification is × 7.

V. 3. Projection microscope of Dubosc-Soleil.

This instrument is signed:

"J. Dubosc-Soleil
à Paris."

It was purchased in 1852 by the Physical Society at Utrecht for *f* 55. It is meant to be used in combination with a projecting lantern and has, therefore, no solar mirror. Inside the illumination tube, which consists of separate telescoping parts, a fixed condenser is fitted on the side of the lamp; on the side of the object, however, is a condenser which can move by rack and pinion. In front of the tube the object-holder is attached, consisting of two plates, clamped together by a spring. To this object-holder a rod is fixed along which the projecting-system can slide by rack and pinion, and there is also a

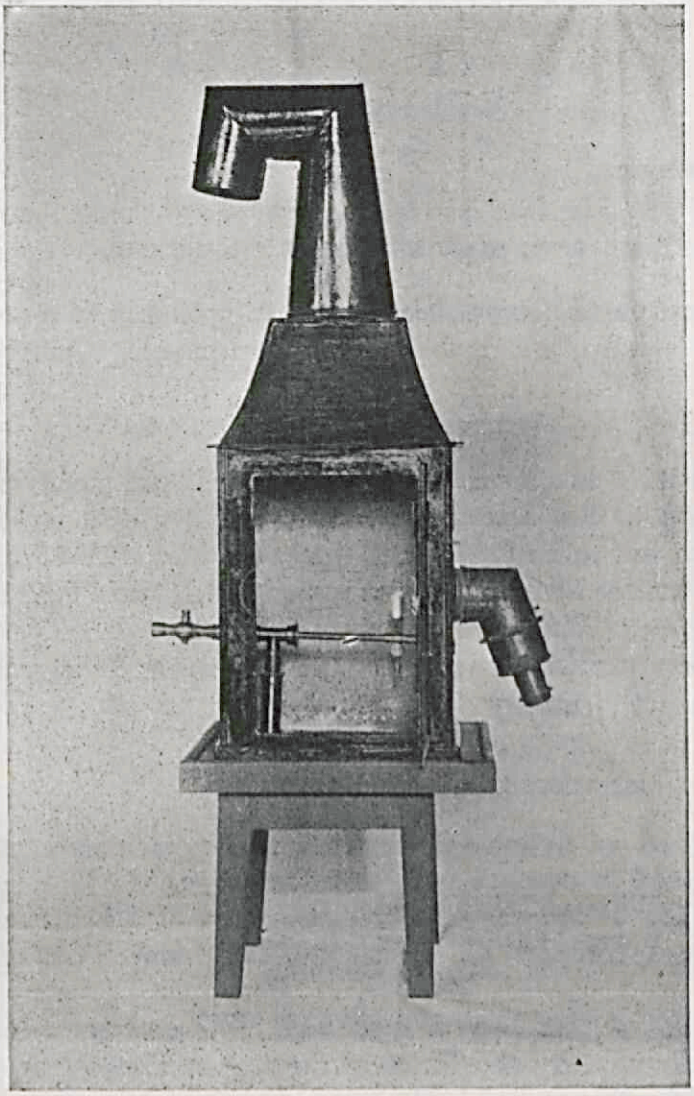

Fig. 41.

screw for sharp focussing. A diaphragm is attached to the front end of the rod to screen off any diffused light.

The projecting system consists of three small achromatic lenses, all alike, each of which, separately, gives a magnification of 9, two together of 17 and all three combined of 24. This last combination can resolve $^{1}/_{100}$ mm.

Moreover, to the front end of the lens-holder a strong negative eye-piece can be fitted, making it possible to use this system for dissecting purposes.

W. Accessories.

W. 1. A vegetable preparation as a micrometer.

A preparation of a vegetable epidermis, probably of a stem, is fixed between 2 small glass plates in an ivory mount. On the mount is inscribed:

"micromêtre de 60 par ligne."

This preparation shows indeed a very regular structure and can be used quite well as a micrometer. The average distance between the stripes turns out to be 0.035 mm, corresponding with 65 divisions per Paris line. On the little box of palmwood is written: *"Micromêtre pour M. le professeur Rossyn* [1])"

It was very probably bought by the Theatrum Physicum about the end of the 18th century.

W. 2. Glass micrometers of Brander.

A small box of palmwood contains two micrometers cut in glass. One is divided in squares with sides averaging 1.111 mm and 0.222 mm; the other in squares with average sides of 1.123 mm and 0.225 mm and in rectangles of 1.123×0.225 mm^2 (Cp. Harting III pg. 409).

On the lid of this box is inscribed *"Micrometers van Brander"*. They were bought by the Physical Society at Utrecht at the end of the 18th century.

W. 3. Case with six micrometers.

This case contains four glass micrometers mounted in brass and also two ivory micrometers. The Physical Society at Utrecht purchased it for *f* 25 from *Newman* in London at the beginning of the 19th century. Each of the ivory micrometers has two mutually perpendicular sets of parallel lines, resp. $^1/_{100}$ inch and $^1/_{50}$ inch, apart, which by their intersection form squares of these dimensions.

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[1]) Prof. *J. P. F. Rossijn* was from 1776 to 1812 director of the Theatrum Physicum of the Utrecht University.

The glass micrometers have also two mutually perpendicular parallel divisions of resp. $^1/_{1000}$, $^1/_{500}$, $^1/_{100}$ and $^1/_{50}$ inch.

W. 4. Micrometer photographically reproduced.

This micrometer is signed:

J. Salleron, 26 Rue Pavée
(au Marais) Paris.

It is mounted in brass and consists of the photographic reproduction of divisions reduced to a very small scale. One division corresponds to 0.059 mm.

W. 5. Test-plate of Nobert.

In 1846 the Physical Society at Utrecht bought, for *f* 12.50 a case containing two test-plates. At present only one is left, which is signed:

Nobert fec. Greifswald.

This plate which is intended to be used for the determination of the resolving power of a microscope by the direct method, has 10 groups of equidistant lines. The mutual distances in the various groups are, according to *Harting's* measurements:

Group	1.	: $^1/_{456}$	mm
,,	2.	: $^1/_{515}$	,, ,,
,,	3.	: $^1/_{613}$	,, ,,
,,	4.	: $^1/_{704}$	,, ,,
,,	5.	: $^1/_{819}$	,, ,,
,,	6.	: $^1/_{956}$	,, ,,
,,	7.	: $^1/_{1115}$	,, ,,
,,	8.	: $^1/_{1302}$	,, ,,
,,	9.	: $^1/_{1515}$	,, ,,
,,	10.	: $^1/_{1964}$	,, ,,

Elaborate discussions on the *Nobert* testplates are to be found in Harting III pg. 412—414.

W. 6. Grayson's test-plate.

The case containing this testplate bears the inscription:

Grayson's rulings
R. & J. Beck, Ltd. London.

The plate itself is of realgar in which 12 groups of parallel lines are cut. Their various distances are:

Group	1.	$^1/_{5000}$	inch	= $^1/_{197}$	mm
,,	2.	$^1/_{10000}$	,,	= $^1/_{394}$	,, ,,
,,	3.	$^1/_{15000}$	,,	= $^1/_{591}$	,, ,,
,,	4.	$^1/_{20000}$	,,	= $^1/_{788}$	,, ,,
,,	5.	$^1/_{25000}$	,,	= $^1/_{985}$	,, ,,
,,	6.	$^1/_{30000}$	,,	= $^1/_{1180}$	,, ,,
,,	7.	$^1/_{35000}$	,,	= $^1/_{1380}$	,, ,,
,,	8.	$^1/_{40000}$	,,	= $^1/_{1575}$	,, ,,
,,	9.	$^1/_{45000}$	,,	= $^1/_{1775}$	,, ,,
,,	10.	$^1/_{50000}$	,,	= $^1/_{1970}$	,, ,,
,,	11.	$^1/_{55000}$	,,	= $^1/_{2165}$	,, ,,
,,	12.	$^1/_{60000}$	,,	= $^1/_{2365}$	,, ,,

W. 7. Camera Lucida after Wollaston.

A telescopic tube is fixed in a table-clamp. Fitted at the upper end of the tube is a small drawing prism which can be placed over the eye-piece of the microscope. Two small lenses (one concave and the other convex) and a diaphragm are hinged on to the prism. The whole of it is contained in a morocco leather case together with the instructions for use, mentioning the following firms as makers of this kind of instrument:

Messrs P. & G. Dollond	*St. Paul's Churchyard.*
Mr. Newman	*94 Soho Square.*
Mr. W. Cary	*182 Strand.*

This instrument was bought from *Dollond* by the Physical Laboratory at the beginning of the 19th century.

W. 8. Camera Lucida after Wollaston.

This instrument bears the inscription:

"Vincent et Ch. Chevalier
Quai de l'Horloge No. 69 à Paris."

On to the mount of the prism two dark coloured pieces of glass and a convex lens likewise of dark glass are hinged. It is a very thoroughly finished piece of workmanship and was bought by the Physical Society for *f* 40.— at the beginning of the 19th century.

W. 9. Camera Lucida after Wollaston.

This instrument bears the inscription:
"P. Berville, 25 Chaussée d'Antin, Paris."

It is a more modern make of camera lucida: the adjustment in height is effected by rack and pinion. With the instrument are 10 small lenses of various powers, which can be inserted in the mount of the prism.

W. 10. Camera Lucida after Oberhäuser.

This instrument was probably made by *Zeiss* about 1880. It consists of a tube, bent into 2 arms at right angles to each other, which contains a reflecting prism. All of it is fitted, instead of the eyepiece, on to the microscope. At the horizontal end is an eyepiece and behind this is a small rectangular prism with a diaphragm. A description of this type of instrument is to be found in: van Heurck pg. 89.

W. 11. Foot of microscope with illuminating apparatus after Harting.

This foot, which is without a microscope, is signed:

J. J. van Dreeven [1]

Nijmegen.

It is fitted with the illuminating apparatus after Harting as described under Q. 2.

W. 12. Wooden slide with dissecting preparations.

This is an old wooden slide with 6 objects contained in a cardboard box.

W. 13. Small mahogany box for dissecting preparations.

A small mahogany box containing numerous dissecting objects mounted in ivory.

W. 14. Oak chest for dissecting preparations.

An oak chest with 9 drawers containing many objects, a number of which are mounted in bone, others on cards.

W. 15. Mahogany chest for dissecting preparations.

This is a very beautifully finished chest with shutter-fastening, containing many objects and dissecting accessories.

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[1]) *J. J. van Dreeven* was amanuensis at the Physical Laboratory at Utrecht. Before then he was established as an instrumentmaker at Nijmegen.

W. 16. Collection of preparations.

This collection consists of a few hundred prepared objects mounted in slides of wood or bone, in ivory caps or on small circles of cardboard.

W. 17. Two microscope lamps.

These are two gas lamps surrounded by metal cylinders with a few openings in them. Glass rods bent to a suitable shape can be fitted with one end in these openings so that the other end reaches underneath the stage of the microscope. The light of the lamp is then forced by total reflection to follow the glass rod and is by this means thrown on to object. The lamps are signed:

"Max Wolz, Bonn am Rhein
resp. *"J. C. Th. Marius Utrecht."*

They were bought by the Physical Laboratory in 1891.

W. 18. Electric microscope lamp after Engelmann.

This little lamp is signed:

G. Kagenaar, Utrecht.

On a round brass foot is mounted a small carbon resistance and an arm; the latter is movable in all directions by means of a ball socket joint. It carries at its extremity a small electric lamp consisting simply of a small glass bead, in which a filament of platina is melted. For description and illustration see van Heurck pg. 106—107.

W. 19. Microtome of Zeiss.

This instrument dates from about 1870. It is signed:

"Carl Zeiss Jena."

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