The Cycloptic®

AO (American Optical) CMO Stereomicroscope

R. Jordan Kreindler (USA)

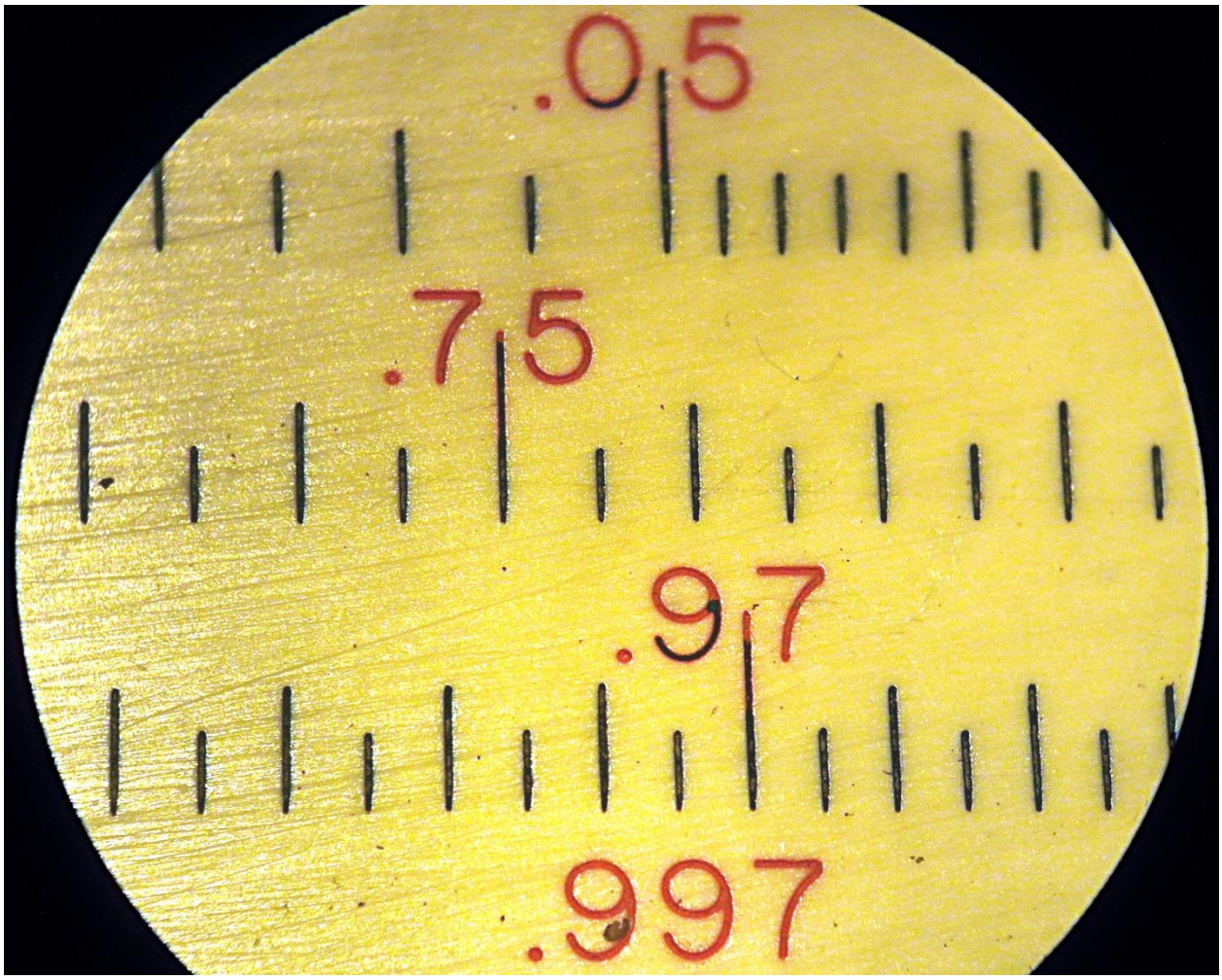


Figure 1. Portion of K&E DECI-LON 6" slide rule, seen through AO Cycloptic microscope in Fig. 8

Background: The Modern CMO

Portions of this Background section are taken from Parts 1 and 3 of the author's June and September 2012 *Micscape* papers on the stereomicroscope.

The first common objective stereo microscope was developed by Prof. John Leonard Riddell of New Orleans, USA c. 1853. Although built by the Grunow Brothers, perhaps the leading microscope maker at the time, it quickly found obscurity. The design of this microscope was later re-discovered independently, i.e., without prior knowledge of Riddell's design, by John Ware Stevenson of England. The Stephenson model was made by a number of manufacturers, including Ross, Browning, Baker, and James Swift and Son.

Fig. 2 shows a Riddell-Stephenson model made by J. Swift and Son.

Although, Riddel-Stephenson style microscopes used a single common objective to obtain stereo images, the objective was small with limited light gathering ability.

The modern CMO (Common Main Objective) microscope, one with a large single objective was developed by Carl Zeiss, Jena in the late 1940s. It was known as the "Citoplast" in East Germany. A similar model was developed by the West German Zeiss Company. See Fig. 3 for an example of the Citoplast and Figs. 4 and 5 for a Zeiss CMO made under the Opton label. (Kreindler, September 2012).

In his book Armin Herman (Hermann, 1991) mentions that the first West German Zeiss-Opton Stereomicroscope was given in a small ceremony on January 23, 1949 to Professor Bauersfeld on the occasion of his 70th birthday.

The Opton CMO version was manufactured by the Opton-Optische Werstatte Oberkochen GmbH Zeiss factory at Oberkochen, West Germany. For a period, versions of this CMO microscope were made by both East and West German Zeiss companies.

The Zeiss Opton-branded CMO was considerably larger than most, then current, stereo microscopes, being taller, wider, and heavier. At 12 pounds, it weighed almost 50% more than, e.g., the c. 1929 B&L Greenough, dual objective, microscope.

Production of the West German Opton version, ceased in 1954, when the name of the West German Zeiss company was changed to Carl Zeiss, about three years before the introduction of AO's Cycloptic (Orlowski, 2012), (Zeiss, undated). An Opton-style CMO microscope continued in production by the West German Zeiss Company until 1959, under the Carl Zeiss label. (Schulze, 2011, 2012). At least until the 1980s, Zeiss West Germany appears to have used CMO designs in their stereo microscopes, except for models 01, 02, I, Ib, III, and the D-series (Kreindler, September 2012).

Figure 2. Riddell-Stephenson style stereomicroscope made by J. Swift and Son

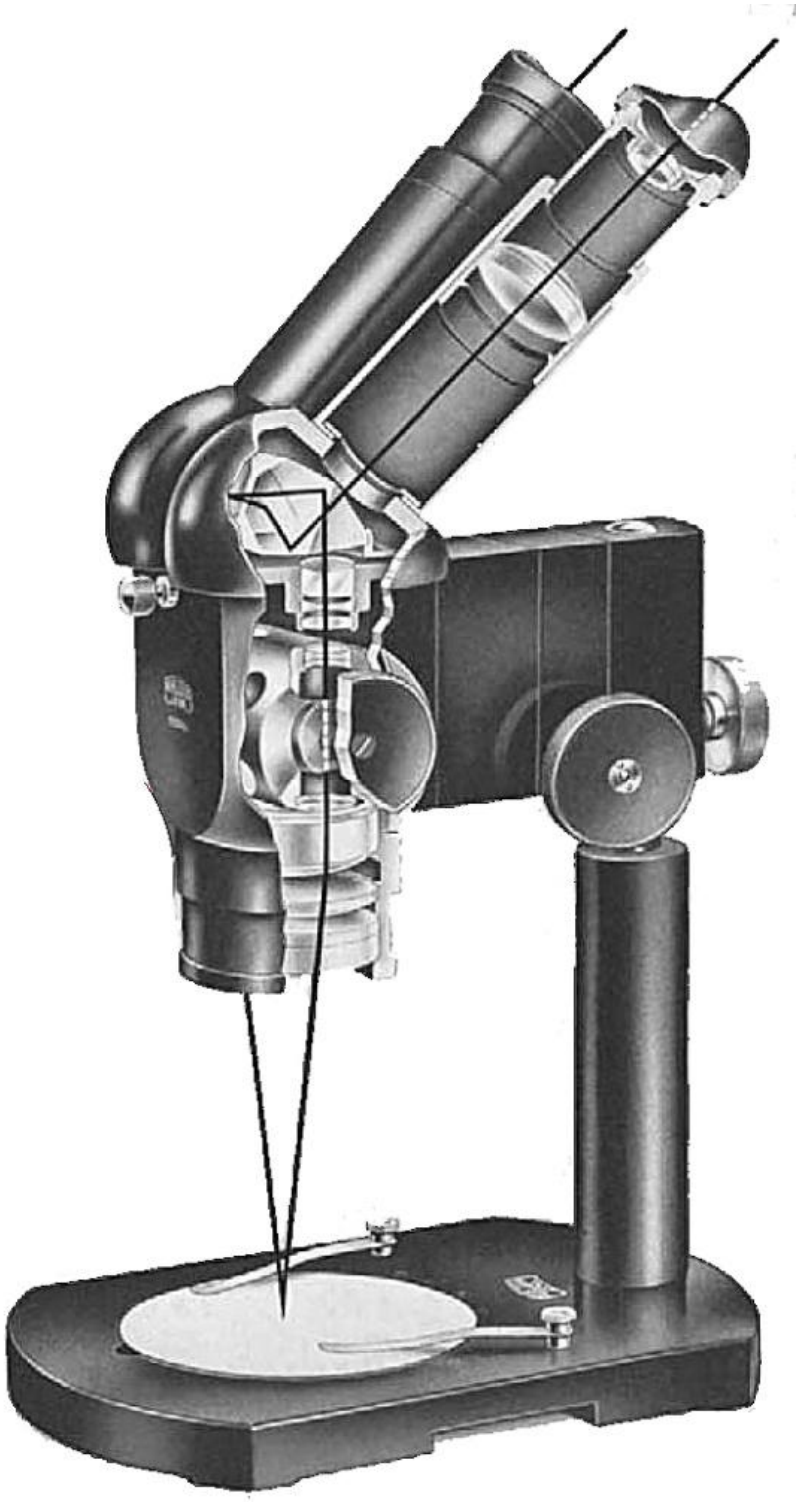


Figure 3. From the East German Citoplast brochure, date unknown. Courtesy, and with permission, of Carl Zeiss Microscopy, LLC (Kreindler, September 2012)

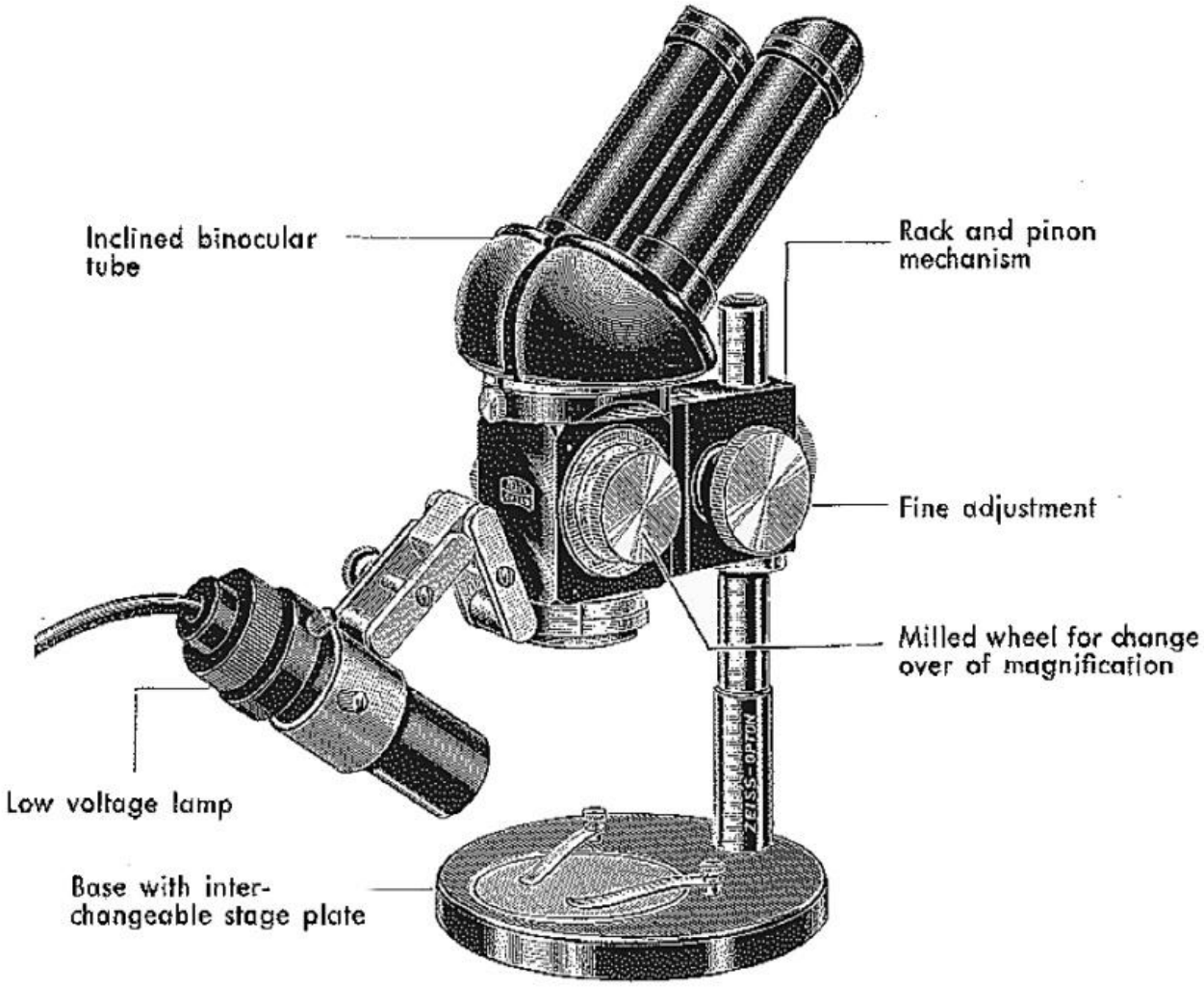


Figure 4. From West German Opton brochure (translated to English), date unknown. Courtesy, and with permission, of Carl Zeiss Microscopy, LLC (Kreindler, September 2012)

Figure 5. Zeiss Opton-branded CMO Microscope
(Kreindler, September 2012)

In CMOs, Fig. 6, a single large objective lens is used, and the image from this single lens is divided into two image paths to provide stereoscopic views.

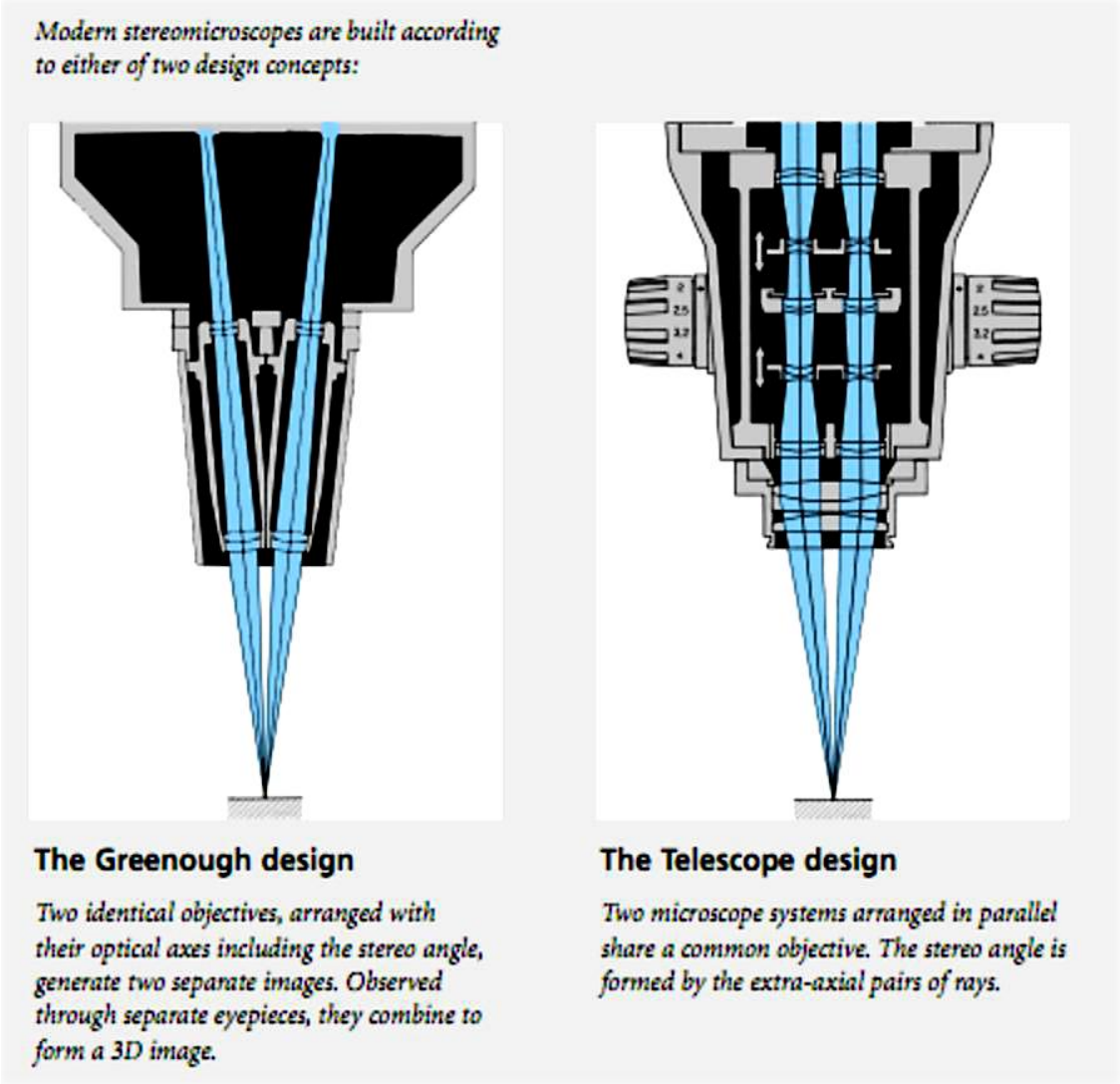


Figure 6. From the Zeiss brochure: *Microscopy from Carl Zeiss. Stemi DR, Stemi DV4, Stemi 2000 Stereomicroscopes, Courtesy, and with permission of Carl Zeiss Microscopy, LLC.* A comparison of Greenough and CMO (Telescope) design microscopes (Kreindler, September 2012)

The American Optical (AO) Cycloptic Microscope

In the aftermath of WW II, any product made in Germany had a hard time getting "traction" in the US and other Western countries' markets. Under these conditions, the first American-made common main objective (CMO) stereomicroscope, AO's Cycloptic quickly became the CMO leader. Although often presented, e.g., on eBay, as if it was a single product, the Cycloptic is actually a variety of different products, with various magnifications, bases, illumination, etc.

AO introduced the Cycloptic in 1957. It came in four basic magnification configurations. These magnification options are shown below for 10x eyepieces.

"F" Fixed 15x magnification
"J": 7x, 15x, and 25x
"K": 10x, 15x, and 20x
"M": 7x, 10x, 15x, 20x, 25x

Series "J" and "K" offered three optional magnification options, while Series M offered five. These "built-in" magnifications could be modified in two ways, by the use of different eyepieces, e.g., 15x and/or by the use of auxiliary lens attachments, e.g., the 2x magnifier. The cost differences between e.g., "K" and "M" models, calculated from the AO price list of August 1975, was about 7% to upgrade to an "M" from a "J" model, and about 36%, to upgrade from the fixed model "F" .

AO released the Cycloptic in a color they referred to as "Dove-gray". Others might call this color steel gray. All models came with inclined viewing tubes, and as with most stereomicroscopes long working distances and erect (non-reversed) images. All models provided for interpupillary distance adjustments.

R. B. Tackaberry, Manager Instrument Development. AO Spencer (American Optical, Unknown) in AO's Cycloptic Reference Manual provides a partial list that sums up some of the microscope's most salient features. The features listed include:

Apochromatic Objectives
Long Working Distance
Full Color Correction
Uniformly Sharp Field
Wide Range of Magnifications
Rapid "Dial-In" Magni-Changer
Reversible Inclined Body
Comfortable 30^{o} inclined body
Dustproof, Watertight, Construction
Permanent Optical Alignment
Erect Non-Reversed Image

Magnification Extending Attachments
Planned Illumination
Versatile Transilluminator
"Cyclospot" Illuminator
Modern Cabinets

Interpupillary Adjustment
Nylon Knobs
Dove-Gray Epoxy Finish
Lifetime Lubricants
Adjustable Focusing Tension
Attached Stage Clips

Coated Optics
Finest Optical System
Rugged Construction Throughout
Modern Functional Styling
200 Precision Parts

3-Element Eyepieces
Highly Corrected Wide Fields
High Eyepoints
Eyeshields
Mechanical Stage Accessory

In their 1977 manual AO (American Optical, 1977) further notes,

The CYCLOPTIC principle utilizes a highly corrected monobjective whose image is examined with a unique binocular telescope system to yield sharp, clear, enhanced stereoscopic image of the full field of view.

Figure 7, Cycloptic common main objective (CMO), apochromatic triplet

The objective of the CYCLOPTIC microscope is a true apochromatic triplet (Author: Fig. 7) *providing a full four inches of working distance.*

The binocular telescope system consists of paired achromatic telephoto lens combinations, unique one piece prisms and new four element wide field, high eyepoint eyepieces which permit comfortable visualization with or without eyeglasses.

It is likely the Cycloptic name, in consideration of the CMO, derives from the one-eyed giant, "Cyclops", of Greek and Roman mythology.

Figure 8. AO Cycloptic model for reflected light, with Magni-Changer "M" (Kreindler, September 2012)

The Cycloptic's CMO lens was an apochromatic triplet.

Fig. 8 shows a portion of the basic binocular Cycloptic stereomicroscope model with Magni-Changer "M". Fig. 9 presents the fixed model "F" without Magni-Changer (see below).

Figure 9. Cycloptic with fixed magnification option

The Magni-Changer

Magnification changes using the built-in capabilities of options "J", "K", and "M" were accomplished using the Magni-Changer. The three magnifications options of Magni-Changers "J" and "K" were obtained using 8 achromatic lens elements. Option "M"'s five choices were obtained using 16 achromatic elements.

> *The "M" Cycloptic* ***Magni-Changer shown*** *in Fig 10, contains four clear openings, in opposite pairs, and two telescopes. The clear openings allow for "straight through" images. The dual paired telescopes have four lens groups each. The telescopes can be rotated into the optical path in opposite orientations. This allows, as with stand-alone telescopes, for the magnification or diminution of images. The drum provides five magnification options. One for the "see-thru" openings, the same in either forward or backward orientations, four additional magnifications using the two telescopes on the drum, in either front or back orientations.*
>
> -- (Kreindler, September , 2012)

Figure 10. AO Cycloptic Magni-Changer

> *This type of magnification changer where the same components are used but reversed to obtain different magnifications is often referred to as a "Galilean drum", as here, as the drum actually contains small Galilean telescopes. These telescopes are frequently composed of plano-convex and bi-concave lenses. Galilean telescopes provide erect images.*
>
> *The Cycloptic, with its Galilean drum and distinctive external markings to show magnification choices has a unique appearance, and has been used in various US TV shows including, possibly the most popular TV drama series of its time, CSI where it was used by Supervisor Dr. Gil Grissom, one of the show's lead characters.*
>
> --- (Kreindler, September 2012)

Magni-Changer's various magnifications can be selected just by rotating the changer. AO refers to this as "dialed-in" magnifications. Owing to the relatively small price differences between the "J" and "K" Magni-Changers and the "M" Magni-Changer, the "M" was the most popular Cycloptic model, as can be confirmed by the large number of previously owned Cycloptic model "M"s that are available for sale today.

The markings at the ends of the Magni-Changer allow for magnification determination for four different optical accessories. For example, in Fig. 8, those optional accessories, identified on the Magni-Changer, can be seen to be the 10x and 15x eyepiece pairs separately and then these eyepiece pairs combined with a 2x auxiliary lens. A quite useful feature of the Magni-Changer is parfocality. That is, the magnification can be changed, i.e., dialed-in, without the need to change focus.

The best way to use a Cycloptic with Magni-Changer is to focus on the object at the highest magnification, with the instrument raised above the position of best focus. The focusing knob is then turned to bring the object into focus. This approach will minimize focus accommodation, and produce a less fatiguing viewing session. Initially focusing at the highest magnification will insure that when the magnification is changed, the object will still be in focus. The Magni-Changer has detents to insure the magnification selected is locked in place. The Cycloptic body has a small indented red dot to allow the magnification in use to be identified, Fig. 11.

As Dr. Cooke recommends it is always best to,

> *... commence the examination with the lowest power of [the] microscope ... the greatest satisfaction will always be derived from a great practical use of low powers*.
>
> -- (Cooke, 1869)

Thus, although the Cycloptic should first be focused with the greatest magnification available, to ensure parfocality, it should then be used at the lowest magnification needed.

Figure 11. Indented red magnification mark

If the detent spring is missing or broken, the spring can be replaced. However, if an available AO alternate cannot be found, replacing the broken spring will require machining work (MacGregor, 2007). Even if the detents are no longer functioning, the scope is still fully useable, if care is taken to line up the magnification choices when turning the Magni-Changer.

Reversible Binocular Body

The Cycloptic viewing tubes can be connected to the microscope's frame either facing toward the supporting column or in the opposite direction. Figs. 12 and 13 show the viewing tubes in both positions.

Figure 12. Viewing tubes facing away from column support

Figure 13. Viewing tubes facing toward column support

The presence of a hinge pin at the joint where the two viewing sections come together makes it easy to change the viewing tubes orientation. Reversing the direction of the tubes is done as follows:

(1) The top of the hinge pin (see Fig. 14) has provisions for the insertion of a spanner wrench. Insert a spanner wrench, or thin needle nose pliers - as the AO spanner wrench is often missing - into the openings on the hinge pin's top and rotate counterclockwise.

(2) Then, continue rotating the hinge pin until it is free from its threads and can be removed (Fig. 15).

(3) Remove the viewing tubes, rotate them 180 degrees Place the hinge pin into the rotated assembly in the alternate mounting hole (Fig. 16), and rotate the pin clockwise until it is fully tightened.

(4) The rotated assembly is now ready to use (Fig. 13).

Figure 14. Cycloptic hinge pin

Figure 15. Cycloptic hinge pin unthreaded

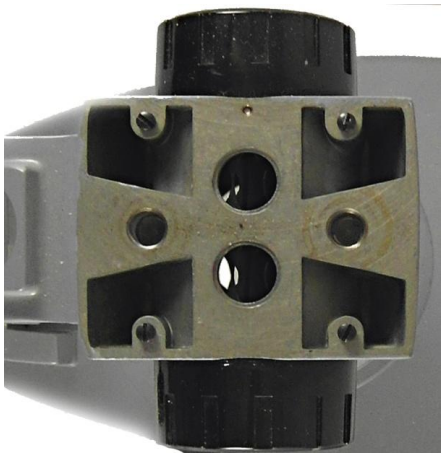


Figure 16. Cycloptic plate showing hinge pin receptacles

Cycloptic Bases

AO offered a variety of bases, including two with phenolic-resin boards, models 30A and 30B. The 30B board was relatively large at 12 x 17 inches. They also offered two table boom stands, models 52S (Table Stand Model) and 53S (Universal Table Microscope Stand). The 52S was a pole stand with a pole boom, while the 53S has an almost pillar-like cross bar section.

However, the most popular Series were the 56 and 59, with single component and dual component bases respectively, and the Series 58, which used the transilluminating base (discussed below).

Figs. 17 and 18 provide photographs of the popular stands, Series 59 and 56.

Figure 17. Series 59 in use, showing post receptacle with locking lever, and separated stage, segments. AO designated these two segments 59-851 and 59-852 respectively (shown here without stage clips).

Figure 18, Series 56
single section base

Accessories

The most commonly found, and/or helpful, accessories are discussed below.

Transilluminating Substage Base with Mirror

Although stereo microscopes are most often used with opaque subjects, they are at times used with transparent ones. For these applications, the "Transilluminating Substage Base with Mirror" is appropriate. This substage base is shown disconnected and with the mirror detached in Fig. 19 and connected to the microscope in Fig. 20.

Unlike most standard, non-stereomicroscopes, here the mirror is rectangular, not round, and fairly large at approximately 2-1/2 x 2-1/4 inches.

The Transilluminating substage base has a rear opening providing for the insertion of an illuminator. Cycloptic illuminators are discussed below.

Figure 19. Transilluminating substage base unconnected to Cycloptic, and with mirror detached

Figure 19. Cycloptic with Transilluminaing Substage Base installed

The mirror is two-sided, allowing for the selection of either a matte or mirrored surface.

The optional substage base is easily added to an existing stand. To attach this base to a Cycloptic stereomicroscope Series 56, do the following:

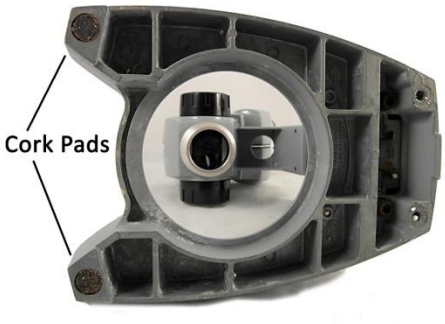
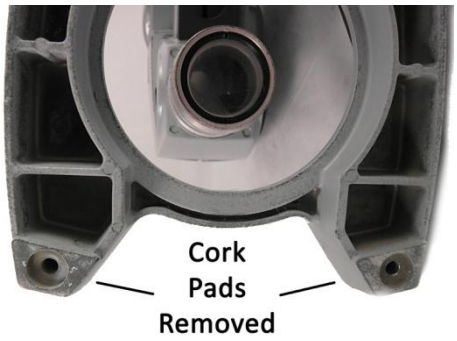


Figure 20. Series 56 cork pads

(1) The base of the Series 56 comes with cork pads (Fig. 20) at the distal ends. These must be removed to allow the bosses (i.e., the two protuberances at the top front ends of the transilluminating base) to mate with the bottom of the Series 56 stand.



(2) Once these pads are removed (Fig. 21), place the transilluminator base, face up, against the bottom of the Series 56 stand so that the locating bosses on the substage base line up with the indentions on the bottom of the stand.

Figure 21. Cork pads removed from Series 56 stand

(3) The locking screws on the substage base can then be engaged into bottom of the stand and tightened. The microscope with substage base is ready to use.

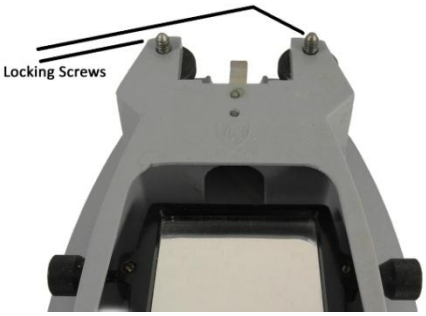


Figure 22. Locking screws on Transilluminating Substage Base

Auxiliary Lens Attachments

Optional auxiliary lens attachments could be obtained for the Cycloptic Series of stereomicroscopes. The most popular of these were the 2X and 2/3X. The 2X attachment was available in two options as either a fixed adapter or a swing out lens. The first two illustrations in Fig. 23 show these options, designated respectively by AO as Nos. 254 and 265. These adapters doubled the magnification, but reduced the working distance to 1.5 inches. The 2/3X attachment identified by AO as No. 267 reduced total magnification and offered a slight increase in working distance to 4.4 inches. The 2/3X option, affixed to a CMO lens is shown as the third illustration in Fig. 23.

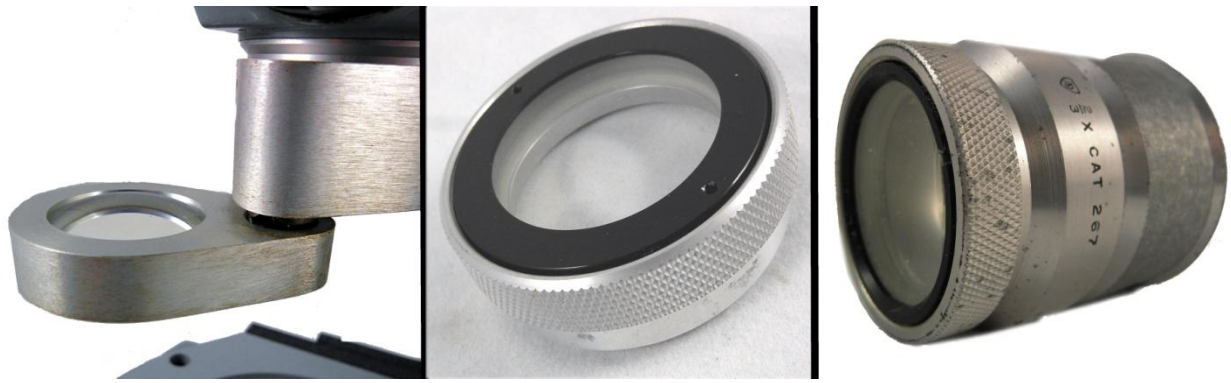


Figure 23. Cycloptic Auxilary lenses (a) 2X Swing-out, (b) 2X fixed, (c) 2/3X mounted

Also available for Series 59 is a 1/2X auxiliary lens, which doubles the working distance to 8 inches. It was rarely used owing to the low resulting magnification. Its use provides a very large field of view. However that magnification and an even larger field of view were probably obtainable, more flexibility and comfortably, using a binocular head mounted magnifier.

Eyepieces, Eyeshields and Reticles

High eyepoint 4 element eyepieces were available in 10x and 15X magnifications. These chromatic eyepieces were parfocal. AO designated the 10X as No. 146 and the 15X as No. 147. No. 146's eye relief is 19mm and 147's 17mm. Their respective fields of view are 20mm and 16.8mm. For non-eyeglass viewers optional hard plastic eyeshields (AO No. 149) are available.

Figure 24. 10X, 20X and eyeshields

The eyepieces could also be fitted with optional micrometer calibrated reticule disks. Eyepiece pairs 10X and 15X, and eyeshields are shown in Fig. 24. A filter, i.e., "Lens Protecting Window" (AO 585), could also be purchased for the CMO.

Mechanical Stage

For those using the Transilluminating Substage Base to examine slides, the mechanical stage (AO No. 1556) was available. This stage could be used in the conventional position or reversed to allow left-hand use. It came with a circular glass stage. A picture of this unit mounted on a Cycloptic with Transilluminating Substage Base appears in Fig. 25.

Figure 25. Mechanical stage, No. 1556

Storage Cases

Storage cases to hold the Cycloptic and some accessories were available for microscopes in Series 56, 58, and 59. Fig. 26 shows a storage case for Series 56, AO No. 1656.

Figure 26. Storage case for AO Cycloptic

Illuminators and Illuminator Mounts

The Cycloptic has provisions for a reflected light illuminator to be placed in the circular cutout at the top rear of the microscope's arm, or to shine light through that cutout into an optional vertical illuminator (discussed below). The Transilluminating Substage Base has a similar circular opening in its rear. This allows the insertion of an illuminator into the Substage Base to project light onto the mirror, to be reflected upward through a transparent or semi-transparent object.

A "new", at the time, "Cyclospot Vertical Illuminator" was specifically advertised by American Optical for use with the Cycloptic (note the similarity in names).

All of the illuminators, but one - the Fluorescent Illuminator (AO 640 Series) - used incandescent bulbs. The two most popular illuminators were the Cyclospot, and the Starlite Illuminator (AO 363V). For some of the illuminators, special sleeves that look somewhat like the housing of eyepieces, were provided.

Figure 27. Starlight Illuminators

Fig. 27 shows two Starlite illuminators, using GE1460 bulbs. They come with flexible multi-section supports, but the lamp could be removed and placed into the circular openings in the top arm of a Cycloptic, or the opening at the back of the Transilluminating Substage Base.

Starlite Illuminators came with fixed or variable transformers. The illuminator on the left, of Fig. 27, (an earlier model) was designed for European mains and that on the right for the US. They provided uniform lighting using fixed pre-focused condensers. The Starlite Illuminator changed little over time.

Figure 28. Starlite Illuminator in use

Here the Starlite Illuminator, Fig. 28, is used with an AO Cycloptic rebranded with the Reichert name. In recent decades, AO was purchased and eventually merged with various companies. AO is now part of the Leica group.

The illuminator mounting sleeves, as mentioned above, are shown in Fig. 29. They were designed so a sleeve could be placed in a circular opening before the Starlite illuminator was inserted. This sleeve is often missing on Cycloptics for sale. *[Author's note: Probably purchasers of these pre-owned Cycloptic stereomicroscopes had no idea what the sleeve was for and discarded it.*]

Figure 29. Sleeves to hold an Illuminator

Fortunately, the sleeve is not required.

AO made other illuminators. One mentioned earlier was the Cyclospot, it is shown in Fig. 30. This was designed, as its name implies, to mate well with the Cycloptic stereomicroscope. It uses a single on/off switch.

Figure 30. Starlite Illuminator

Another popular illuminator was the AO model 653 Universal Microscope Illuminator. In one AO brochure, this is described as having a, *... three-link jackknife standard and with 6.5 volt, 2.75 ampere bulb, clear blue glass, ground glass filters and No. 651 Variable Transformer, UL and CSA Approved.* (American Optical, Unknown-2). This was designed to connect to the hinge pin and shine light into a Vertical Illuminator that mounts over a Cycloptic CMO or auxiliary lens attachment. The illuminator contains a multiple lens system that allows the viewer to focus the

light beam. A picture of a Universal Microscope Illuminator, with an optional blue filter mounted, is shown in use in Fig. 31 (note the adapter arm with screw connected to the hinge pin).

Figure 31. Vertical illuminator using a lamp supported at the hinge pin. On the stage is hemimorphite (a common sorosilicate) on limonite (hydrated iron oxide - thus the color).

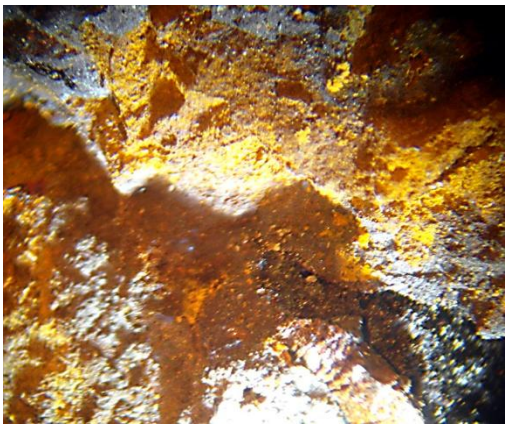


Figure 32. Limonite as seen using Vertical Illuminator

The Cycloptic shown has an opaque white stage plate, and lacks slide clips, as is appropriate for examining thick non-transparent objects. The vertical illuminator contains two reflecting surfaces. The first reflecting surface catches the light from the lamp and reflects it across to the second, which sends it down to the object. This overhead, rather that oblique, illumination allows for the inspection of, e.g., objects with deep cracks or crevices, such as borings in machined parts or for medical procedures where lighting might otherwise be difficult. AO also provided an Internal Vertical Illuminator (K1730) as well, which had its own lamp.

The use of any reflected light illuminator with the Cycloptic requires the viewing tubes be turned away from the support column, as shown in Figs. 31 and 33, so the cylindrical opening for inserting the illuminator for direct lighting, or shining light through the arm's opening, is accessible.

Trinocular Cycloptic (The Photographic Tube Adapter[PTA] - AO No. 638)

The PTA is used to convert a binocular Cycloptic into a trinocular. It is easily attached, and focusing is then as normal, but it allows for a flip-up/down mirror to send the light from a binocular tube to the PTA for photography. That is, the trinocular Cycloptic is not a separate microscope, but a binocular with the optional photographic adapter attached.

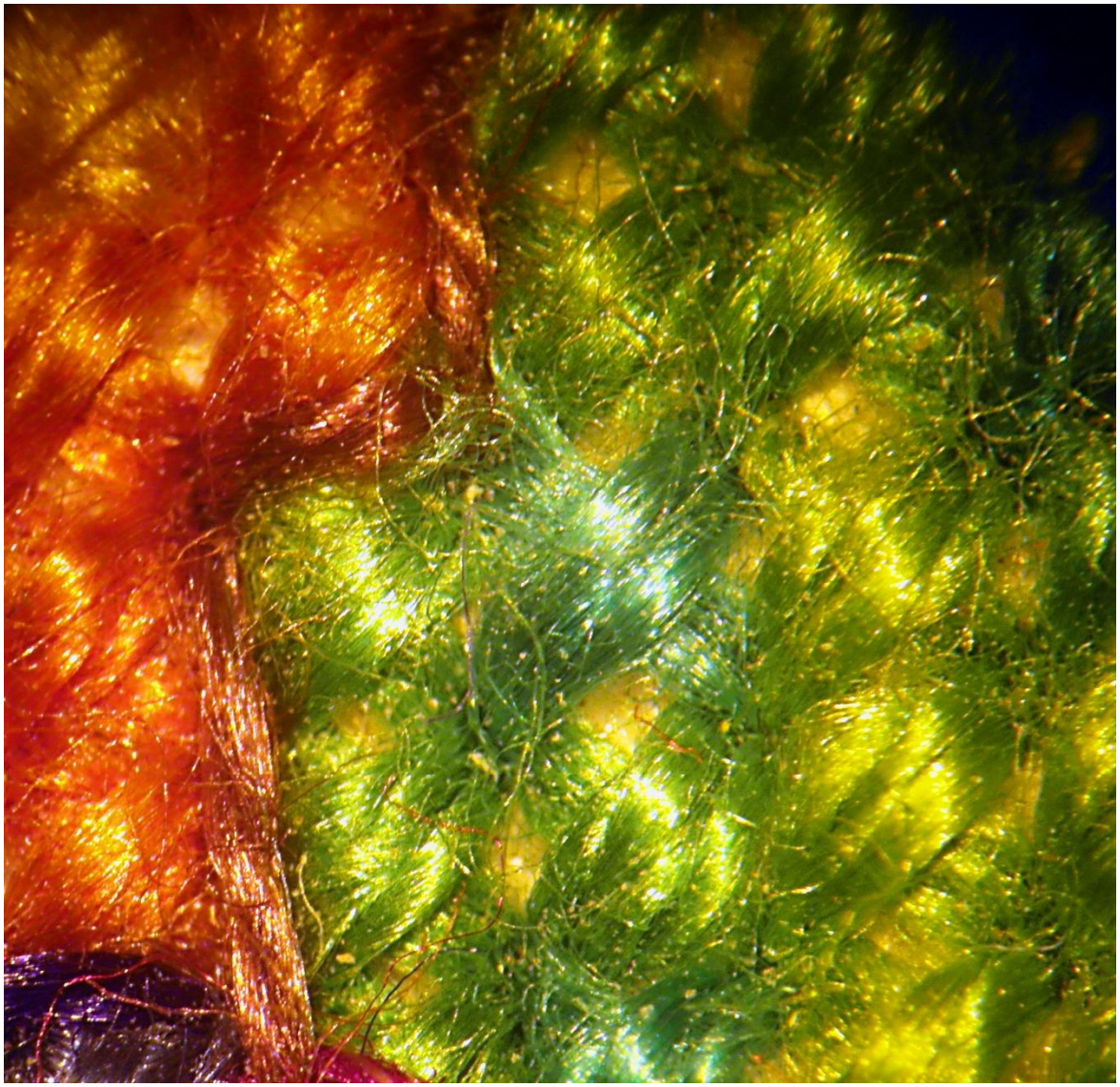
An example of a trinocular Cycloptic with 2X auxiliary adapter, mechanical stage, and dual Starlite Illuminators is shown in Fig. 33. This is a heavy instrument. With the two illuminators, it weighs about 15 pounds.

Unfortunately, owing to the displaced vertical location produced by the PTA, which raises the height of the arm, the Vertical Illuminator cannot be used appropriately with the Photographic Tube Adapter in place.

Figure 33. Cycloptic trinocular with mechanical stage, 2x auxiliary adapter and dual illumination

The focusing tension on all Cycloptics can be adjusted by holding one coarse focusing knob and turning the other. This is particularly helpful if heavy accessories are used.

Figure 34. Closeup of fabric seen through Cycloptic microscope, 25X



Afterward: Non-Cycloptic AO Microscopes a Caution

A caution: AO Series 40 microscopes look somewhat similar to Cycloptics, particularly as they also have similar locations for Magni-Changers. Fig. 35, shows an AO Model 40RT. AO used RT to indicate microscopes that include illumination for both reflected (R) and transmitted (T) light. The model 40 might be mistaken for a Cycloptic "F", with a fixed magnification of 15x. However, this, and other Model 40 style instruments are Greenough, not CMO microscope, (i.e. they use two objectives not one). The models 40s are attractive instruments, but were relatively inexpensive and designed primarily for student use.

Shown in Fig. 36 is an AO Model 42RT allowing two magnifications, 10x and 20x. The AO marketing team apparently liked the term Magni-Changer, as the magnification changer on the Model 42RT, is also referred to in the AO literature as a Magni-Changer. However, Model 40 Magni-Changers do not have the distinctive knob-end markings found on Cycloptic Magni-Changers (See Cycloptic Magni-Changer above).

The model 43RT looks almost the same as the Model 42RT, but offered 15X and 30X magnifications. Models 45 and 46, which offer zooming, are also part of the Model 40 Series. However, these models have black bodies, and so are unlikely to be mistaken for Cycloptics.

Figure 35. AO Greenough microscope Model 40

Figure 36. AO Greenough microscope Model 42

References and End Notes

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Although the Cycloptic is a landmark in American stereomicroscopy, the common objective concept was first used by Riddell in 1850s, and a common large objective was later implemented by Zeiss in their Citoplast, considerably before the Cycloptic was introduced.

Orlowski, Kristen and Dr. Michael Zölffel (private correspondence, 2012)

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