Stereo Microscope

Part 2a: Greenough Microscopes
3rd Edition

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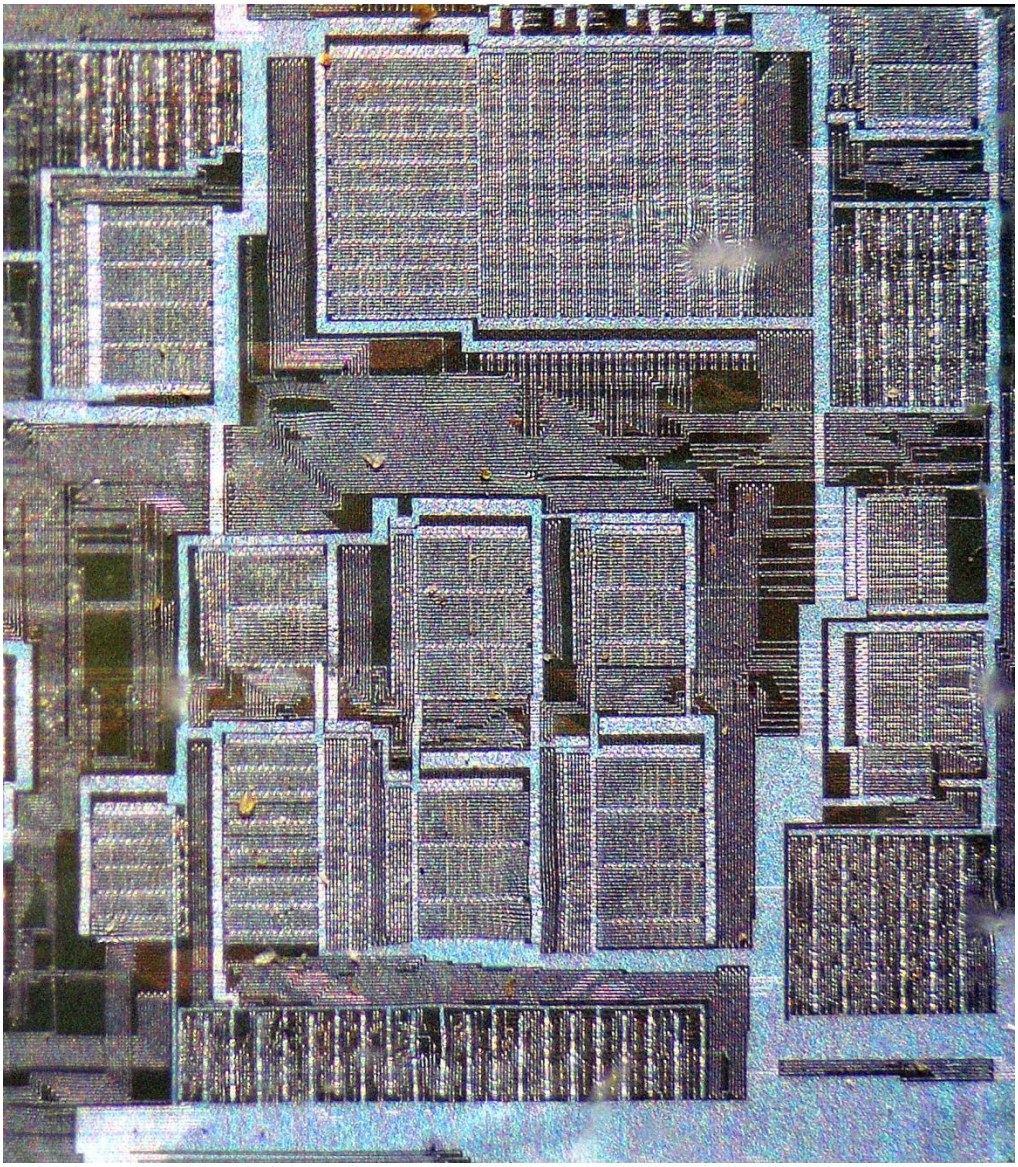


Figure 20. Damaged IC through Greenough Microscope
(See text for more detail)

Background: The Greenough Microscope

In the nineteenth century dissecting microscopes were commonly simple microscopes, Fig 21. Early in the 20th century these were primarily of lacquered brass, with an increase in black enameled areas as the century progressed. At the turn of the 20th century there were increasing demands for improved capabilities from scientists, who were then more frequently using microscopes for analyses. This, along with the advancement of technology, led to many single element simple microscopes being upgraded to short tube monocular instruments containing more complex eyepieces. Whether simple or compound instruments, dissecting microscopes were usually identified by the presence of sides-of-stage screws to connect hand rests, Figs. 23 and 24. These rests made dissecting work less physically demanding.

However, even with the introduction of short tube instruments, the demand for greater capabilities continued. In response to this demand, microscope makers increased the size and complexity of their instruments to increase sales and satisfy user demands.

With the development of the Greenough stereo microscope (see below), capabilities took a significant step forward, with further increases in size and weight. At the start of the twentieth century, dissecting microscopes changed from relatively small portables to benchtop instruments, although smaller instruments were still available.

The new Greenough dissecting microscopes were initially designed as modifications to existing biological compound microscopes. These usually included larger stages, greater working distance between object and objectives, and often saw the absence of substage assemblies, as most dissecting work was done using reflected rather than transmitted light.

Figure 21. Dissecting microscope

Greenough Stereo Microscopes

The Greenough stereo microscope was invented by American Horatio Saltonstall Greenough. [As an aside, Mr. Greenough was the son of, the same named, Horatio Greenough, one of the first American sculptors to gain international recognition.]

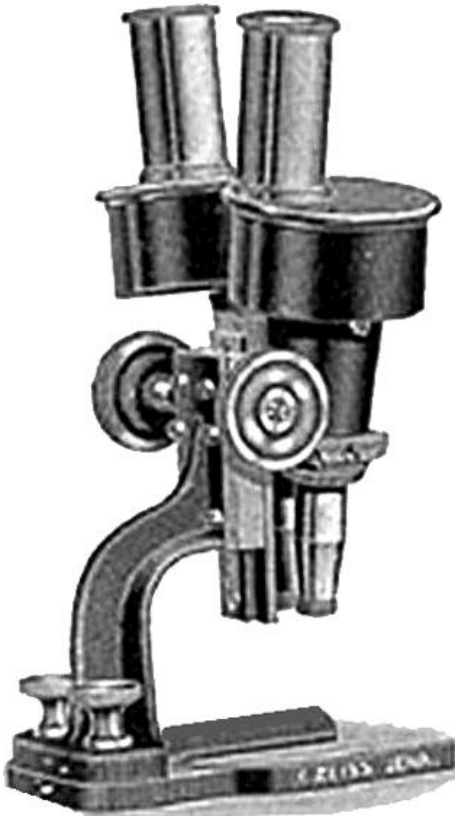


Figure 22. First Modern Stereo Microscope Zeiss - Greenough Design c. late 1880s

A Greenough stereo microscope uses dual Porro prisms (named after inventor Ignazio Porro). These internally reflective prisms are used to provide erect images to the eyepieces from light paths which pass through two adjacent objectives, as opposed to the single objective designs of Riddell and Wenham.

Today, Porro prisms are commonly used in microscopes and binoculars. Porro prism instruments are easy to identify owing to the relatively large tell-tale right angle turn in the viewing path.

Greenough stereo microscopes are still widely use today. They provides images of objects that are not reversed as is typical with compound high power microscopes (Wade, 1998). Their design is derived from the monocular compound microscope, but here with dual paired microscopes working in unison.

Mr. Greenough was living in Europe at the time he designed his stereo microscope. He met Ernst Abbe, of the Carl Zeiss company, at a hotel in the university city of Jena, Germany in 1886. Greenough drew a, now famous, diagram of his stereo microscope for Dr. Abbe.

At the time Zeiss was possibly Europe's leading microscope maker, and the timing of the meeting was fortuitous. Ernst Abbe was the world's leading expert on optics, and had become Zeiss' partner about a decade earlier in 1875. Dr. Abbe owned about 45% of the Zeiss company. He had the technical abilities to understand and improve Greenough's concepts, and was in a position to insure its development.

Greenough microscopes are designed for relatively low magnifications and long working distances. They are typically provided with the capability to adjust the separation of both binocular tubes to accommodate the interpupillary distance appropriate for individual users.

As Marvin Reimer notes (Reimer, 1962), [Greenough] stereo microscopes are low magnification instruments of necessity. Two objects cannot occupy the same space simultaneously. So, there is a physical limitation on how close the objectives can come to each other. That is, at some point they can be brought no closer.

Although the Greenough's concept was presented to Dr. Abbe in 1886, it took some engineering modifications before Zeiss produced the first commercial Greenough stereo microscope in 1897, Fig. 22. This was known as the *Greenough double microscope of Zeiss design*.

The Zeiss company has continued the Greenough design for over 115 years. Zeiss catalogs for its Stemi (Stereo microscope) series use the tag line, "*Conceived by Greenough, Realized by Zeiss*".

A discussion, including engravings, of a slightly later Zeiss Greenough stand, and an engraving of its light paths can be found in The *Journal of the Royal Microscopical Society* (RMS), (RMS, 1898).

The illustration of this microscope, Fig. 23, shows its debt to the first Zeiss Greenough, Fig. 22. It includes changes such as a one piece stand with substage mirror. It shows the hand rests and relative dimensions of components of the microscope's body, and provides a link from the original Zeiss Greenough as it evolved to Zeiss Stands XA and XV, Figs. 24 and 30.

Fig. 24 shows a Zeiss, Jena stereo Greenough design about three decades later, c. 1930/31. Stand XA is one of the variations of Stand X which was sold in different configurations depending on use.

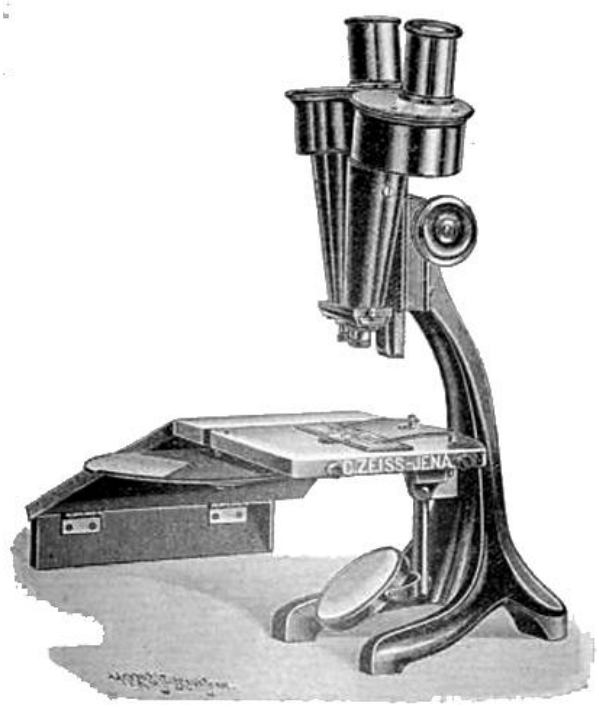


Figure 23. Fig 77 (RMS, 1898)

Figure 24. Carl Zeiss, Jena Stand XA, c. 1930/31

To quote from the Zeiss catalog of 1934,

> *In these [Greenough] binocular image erecting microscopes, two complete tubes, each with one objective and one eyepiece and inclined at an angle of eight degrees to the perpendicular, are combined into a "double tube" ... [T]he observer receives a stereoscopic impression of the object, whilst the exit pupil is fully utilized. ... The instruments of this class are principally intended for dissecting purposes at low magnifications ... With the necessarily small numerical aperture of the objectives, magnifications exceeding 100 X must, however, be considered empty magnification.*
>
> -- (Zeiss, 1934)

Zeiss notes that regardless of the configuration chosen for Stand X, all versions of this stand used the same double Greenough tubes (Zeiss, 1934). This Zeiss Greenough microscope, like the Bausch and Lomb Greenough of roughly the same decade, Fig. 25, is provided with removable, replacement objectives in its standard configuration.

Removable objective sets for Stand X was available in seven different objective magnifications. This Stand was also available, somewhat later, with a conventional-style triple turret, for purchasers comfortable with three magnification options. For these purchasers Zeiss modified this stand so that objective sets, shown here with Stand XA, could be used on a rotatable turret. Although this turret was, obviously an afterthought and looks "tacked on", it allows magnification changes to be made without the need to remove and replace objective sets.

Stand X was designed primarily for dissecting, so it's no surprise that hand rests are provided in the standard package. The example here comes with three pairs of objectives 4x, 8x, and 12x that are similar in size to the same objective magnifications on Zeiss's Stand XV, Figs. 29 - 31. There are three pairs of eyepieces, two Huygens 7x and 15x, and a surprisingly high magnification, 28x orthoscopic. (It is surprisingly high considering the low numerical aperture of this stereo microscope's objectives.)

Thus, depending on the combination of objectives and eyepieces, there are nine different possible magnifications, although some combinations provide only empty magnification. Considering the non-availability of computer-design lens software at the time of its design, Stand XA provides surprisingly sharp images. It comes with a pair of angled wooden hand rests, the proximal edge or each connecting to the sides of the microscope's stage and the distal edges sitting on the same flat surface the microscope rests on.

It allows for both incident light and transmitted light via a 70mm substage mirror. However, an external light source is required for incident lighting. The microscope is stored in a purpose-built wood case that holds the hand rests, the three objectives pairs, and eyepieces.

Stand X was manufactured from 1926 t0 1942.
Because of their intended use as dissecting instruments, it is usual for stereo microscopes made in the first half of the 20th century to come with detachable "hand rests", such as shown here. These hand rests are typically made of metal and wood, and occasionally all metal.

The Zeiss microscope in Fig. 24 rests on a horseshoe base, and provides coarse focusing via rack and pinion, adjustable using either the left- or right-side knobs. Although this is a Greenough stereo microscope, it's apparent from its stage clips, stage opening, and substage mirror that its design owes much of its heritage to the biological binocular compound microscope. It has a relatively large substage ring (not visible in the photo) that provides options for circular opaque white and black backgrounds, and an opening containing a short open cylinder to hold a condenser or other lens, as is common in biological microscopes. The Zeiss' 1934 catalog (Zeiss, 1934) shows Stand X with a slide on its stage, lending further support to assumptions of its biological compound microscope heritage.

This microscope in its case with accessories weighs 16 pounds 9 ounces, and without its case 7 pounds 2 ounces. It is approximately 13 inches tall as shown, and with its hand rests attached about 19 inches wide. Clearly, this was designed as a benchtop instrument, rather than for field use.

The relatively low magnification of stereo microscopes is accompanied by relatively low resolution, compared to higher power compound microscopes. However, this resolution loss is not an issue as more of an object is seen. That is, resolution reduction is balanced by an increased field of view.

Early 20th century stereo microscopes closely followed Zeiss' Greenough design and were fairly popular, as can be confirmed by the extensiveness of contemporaneous advertisements, and the number of these instruments still available today on the used market.

One example is the Bausch and Lomb (B&L) Greenough microscope in Fig. 25. It is shown here with two pairs of detachable and exchangeable objectives. [Notice the B&L design is similar to the first Zeiss Greenough, Fig. 22, and later contemporary Zeiss Greenough microscopes Figs. 23 and 24.]

In 1929 the price of this B&L microscope with one pair of 40mm objectives and 10x eyepieces was USD $126, with a second pair of objectives $149.50, and with a set of three paired objectives $177.50.

To provide an additional sense of the size and weight of these early Greenough designs, the B&L Greenough Microscope shown in Fig. 25 is, approximately 13" tall and weighs 9 pounds. So, it is slightly heavier than the contemporary Zeiss Stand of Fig. 24. It comes with a substage mirror for transmitted light. As with the Zeiss models discussed previously, external Illumination is required for incident lighting.

Figure 25. B&L Stereo Greenough Microscope Model KA c. 1929

Figure 26. Photograph through B&L Greenough Microscope

Fig. 26 is a photograph through the microscope in Fig. 25, with its 55mm objectives mounted. It shows a portion of the Treasury seal on a U.S. one dollar bill. It represents one of the applications, i.e., checking for counterfeit currency, for which these microscopes were used.

As can be seen from the picture, images through this over 80 year old microscope still come into sharp focus, with good contrast, and are reasonably flat across the full field of view.

Bausch and Lomb also marketed a range of stereo microscopes using drum-like turrets rather than the replacement objectives option of Fig. 25 in their 'K' style stereo instruments. These were available with either tilted or untitled body tubes Figs. 27 and 28, and Allen (Allen, 1940) show pictures of some B&L K style stereo microscopes. These instruments were sold for, perhaps, three decades, with only modest changes over time.

Figure 27. - B&L Model BKT-5 with Stand B, rotating turret, and tilted eyepiece tubes, c. 1950,

Figure 28. B&L stereo microscope AKW-5 with Stand A and non-angled eyepiece tubes, c. 1940

Figure 29. Zeiss Stand XV objectives detail

Greenough-style stereo instruments use paired dual microscopes, each with their own objective. So, the standard-style nosepiece used on a traditional compound microscope when used on a stereo microscope needs a relatively larger diameter to hold the dual objectives needed for each magnification change. In spite of these size considerations, a number of companies used traditional-style turrets.

The Zeiss Stand XV, c. 1930s, uses a standard-style, and quite large, quadruple turret with four pairs of objectives, Fig. 29. As expected, this turret design on a stereo instrument makes the microscope's width significant, and gives it a unique and unmistakable appearance. There were only 730 copies of Stand XV made between 1934 and 1942 (Gubas, 2008, 2012).

Although some Stand XVs may have been destroyed during World War II, or lost to natural attribution over time, others exist and I would be pleased to receive information about them.

With its metal hand rests attached, the Stand XV's stage and hand rests are somewhat reminiscent of a Klingon *Bird of Prey* warship from the TV and movies series *Star Trek,* Fig. 30. While developed for function, this Stand is also, in my opinion, an attractive work of modern art and design.

It has four pairs of objectives 2x, 4x, 8x, and 12x magnifications. The example shown here comes with two sets of eyepieces, 8x and 12x. It is housed in a wood case with built in storage areas for the microscope, its hand rests, stage plates, and extra lens sets.

On page 19 of the Zeiss catalog of 1937 (Zeiss, 1937), Fig. 31, there is an engraving of this model with accessories and attached electric illumination, where this model is identified as a *Stereoscopic Dissecting Microscope Stand XV.*

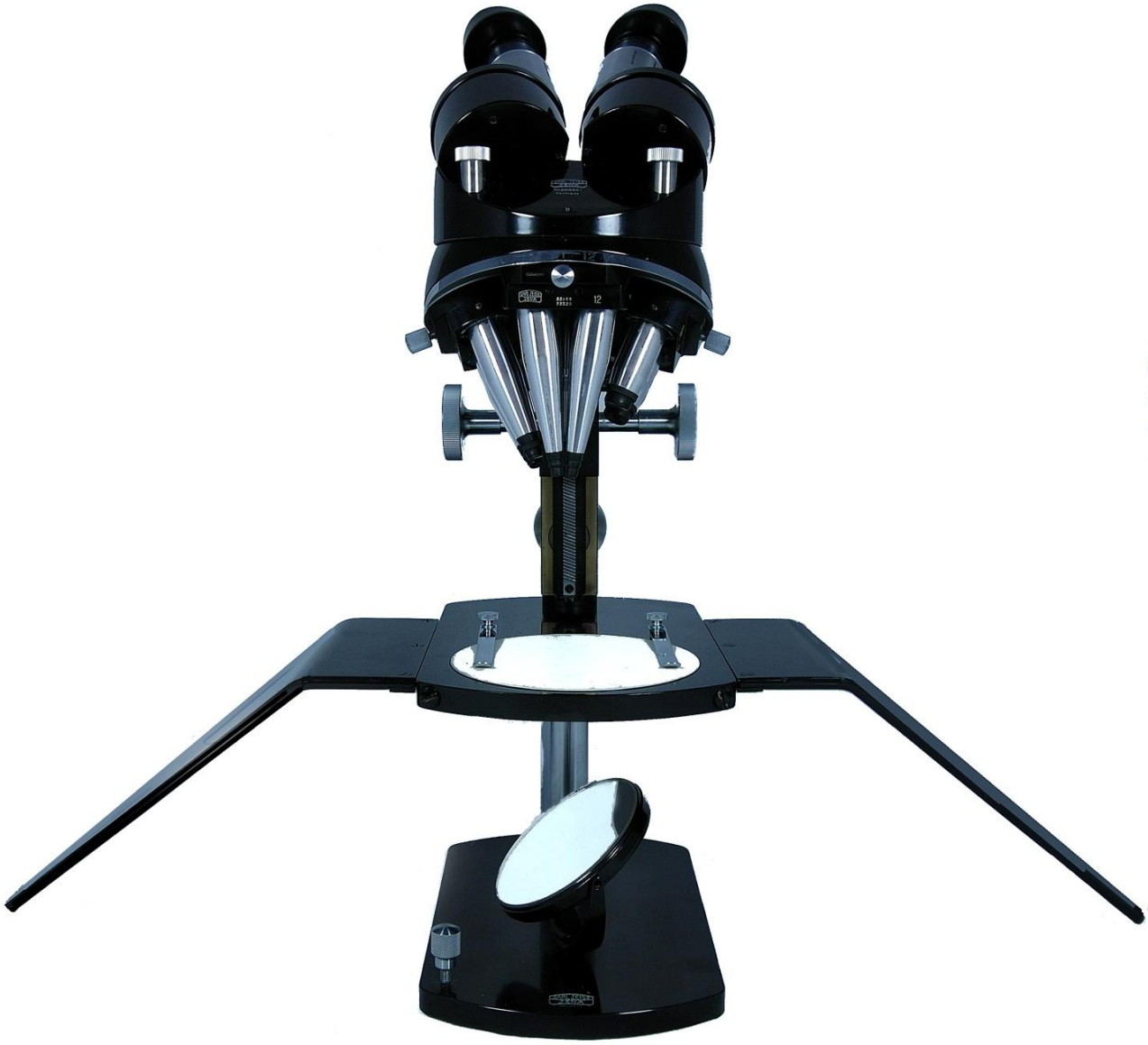
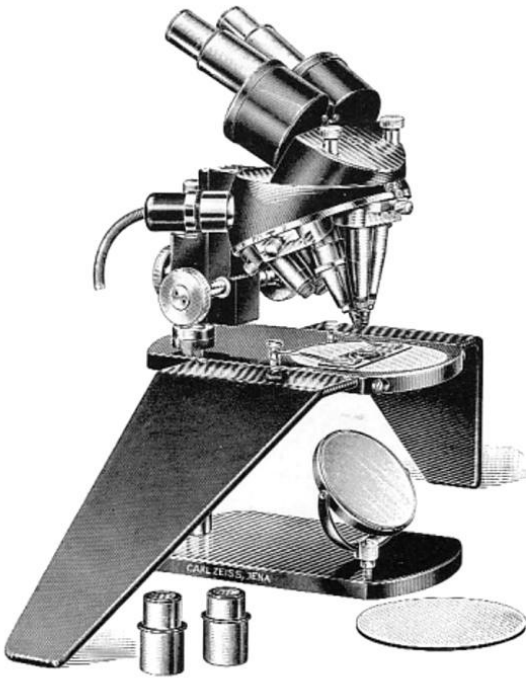


Figure 30. Zeiss Stand XV



Stand's XV's unenclosed objectives,, Fig 29, which are similar to other contemporary manufacturer's models, possibly made then less stable then the enclosed, and better structurally supported, later objective pairs that followed, Fig. 32. Although my Stand XV's objective pairs show no signs of instability.

Perhaps, because of its large size, relatively high price, and limited sales, Zeiss discontinued production of the Stand XV after the war.

Figure 31. Zeiss Stand XV, Courtesy. and with permission, of Carl Zeiss Microscopy, LLC

A less ambitious and more traditional standard-style turret was used by the AO Spencer company on their AO Series 25, Fig. 32, and AO Series 26 Greenough microscopes. These microscopes were available with double or triple objective sets on a revolving nosepiece. The triple objective pairs obtained magnifications of 1X, 2X, and 3X. This design was less popular than the later drum-style turrets, Figs. 27 and 28, which allowed for a smaller and, arguably, more attractive microscope. However, standard-style turrets were used by a variety of stereo microscope manufacturers.

Stereo microscopes using standard-style turrets are still manufactured with dual sets of objectives. Dual objective magnifications on a stereo microscope, allow for a nosepiece relatively similar in size to a quadruple nosepiece on a compound microscope. Stereo objectives, on later microscopes, are often surrounded by a protective metal housings, Figs. 39 - 42.

Greenough microscopes provide excellent 3D images, and with modern computer designed objectives and eyepieces have widefields and high resolutions.

Figure 32. AO Model 25GL, Courtesy, and with permission of, Jay Stanley, and Classic Optics

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(This list includes references/notes for the full paper. However, additional references may be added in later Parts)

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