# Who was Horatio Saltonstall Greenough?
## Part 4

Berndt-Joachim Lau (Germany) R. Jordan Kreindler (USA)

### 18. His Supplier's Experience in Dissecting Microscopes

The first microscope model manufactured by Carl (Friedrich) Zeiss (1816-1888) was a dissecting one using a doublet as a strong loupe. In 1846 Zeiss founded his workshop at Jena, Germany and in the following year he took on a single trainee, August Loeber (1830-1912). In 1857 he became the first foreman of the growing company [Paetrow, 2016].

Figure 54 Dissecting Microscope by Carl Zeiss in 1848/49, Mounted on Housing Box (Courtesy Prof. Timo Mappes, http://www.musoptin.com).

Carl Zeiss's master Dr. (Johann Christian) Friedrich Koerner (1778-1847) was suggested for designing dissecting microscopes by the botanist Prof. Matthias Jacob Schleiden (1804-1881), both at Jena about 1840. Schleiden is known as an expert in microscopy and cofounder of cell theory. Each of Koerner's microscopes were checked by Schleiden before delivery. After Koerner's death, Carl Zeiss launched his own dissecting microscopes.

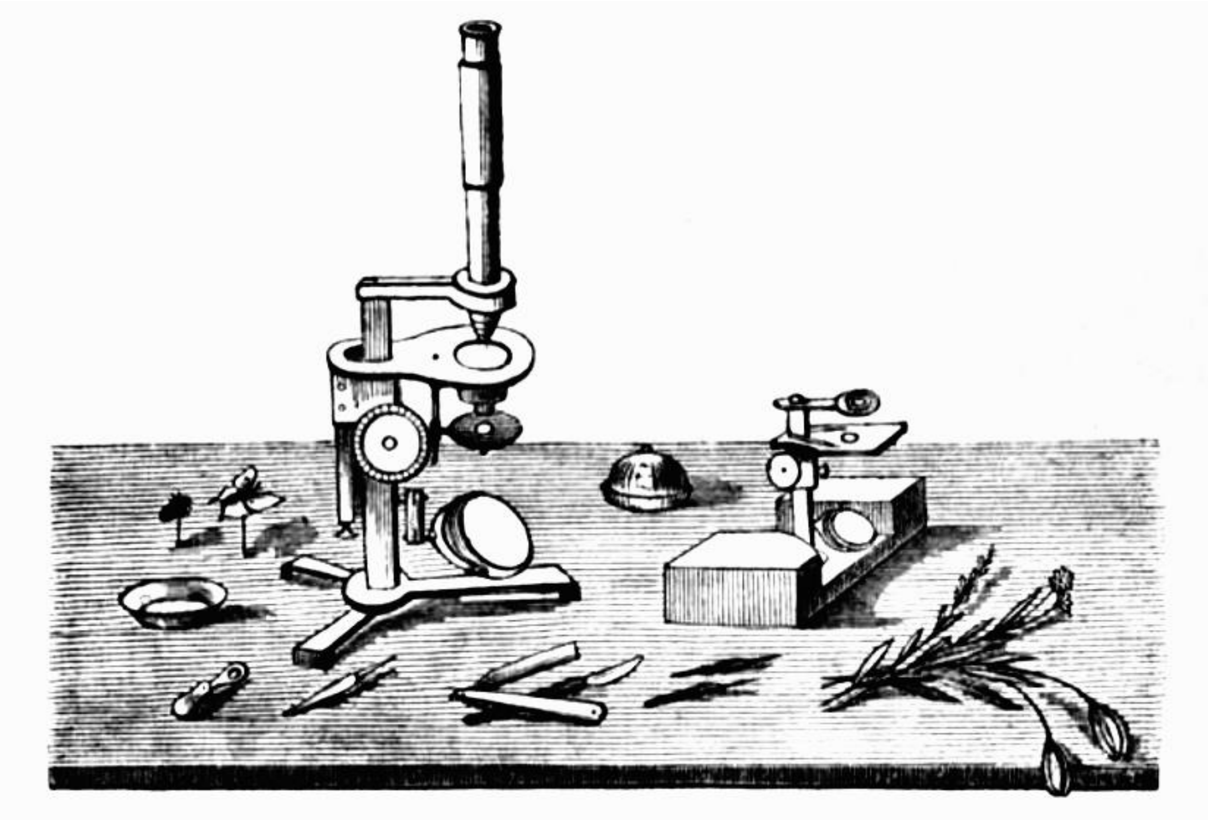


Figure 55 Schleiden's Equipment Inclusive Dissecting Microscope [Schleiden, 1848].

Schleiden's former assistant and botanist Hermann Schacht (1814-1864) bought the first sample of Zeiss's microscope [Paetrow, 2016] and described its drawing on Fig. 2 of frontispiece of his book [Schacht, 1851]:

“The simple microscope by Zeiss intended for preparation (1/3 of the true size). **a** The double lens; **b** the arm which carries it and which can be moved up and down as well as pushed sideways on the ground rod; **c** (with this arm one gives the rough adjustment); **d** screw is used for fine adjustment; **e** is the fixed object table; **f** the sliding collecting lens under it; **g** the mirror; **h** a spring, which makes the fine adjustment more uniform. **I, i,** are the two cheeks of the heavy wooden block in which the stand is inserted; the latter, however, can also be attached to the box that houses the microscope and the other lenses. “

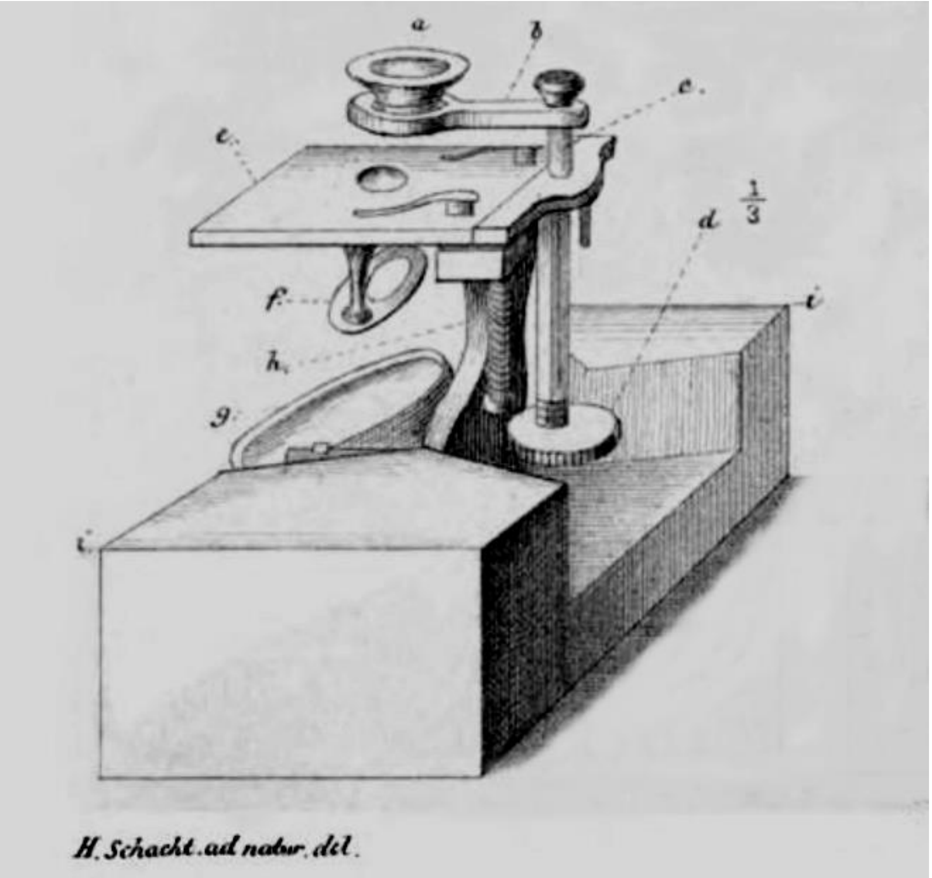



Figure 56 Dissecting Microscope by Carl Zeiss in 1847, Mounted on Wooden Block [Schacht, 1851].

“2. A simple, preferably double-lens microscope ... I have been working with such an instrument from Carl Zeiss in Jena for several years and I can highly recommend the same. Such a simple microscope has 3-4 double lenses, the magnification of which is 15, 30, 70 and 120; the focal distance of the third lens is so great that it can be used for preparation, albeit somewhat uncomfortably.

If you have a compound microscope, you will be able to do without the last double lens with which preparation is not possible. The table is immobile, the setting is double, a collecting lens is attached above the plane mirror, which can be pushed aside. The price of such a simple microscope with 3 double lenses is 11 Thlr. Pr. Cour. (*French: Thaler Prix Courant = Thaler list price*, the authors); on the other hand, with 4 lenses 13 Thlr; the wooden block with the cheeks is added on request for a moderate price. Similar instruments, at the same price, but constructed somewhat differently, are made by the son of the late Dr. Körner (Bernhard Körner in Jena). Messrs Bènéche and Wasserlein in Berlin also supply them.

3. In the case of the double loupe constructed in the manner of the oculars, the problem is remedied, and as a rule they have a large field of vision, which gives a correct picture in its entire extent; they can also be used very conveniently on the stand of the aforementioned simple microscopes ... C. Zeiss in Jena has such a Loupe of 5x, another of 12x magnification; both are highly recommended.”

Here we may mention the later Dissecting Stand I after Paul Mayer (1848-1923). For the observation of larger objects, particularly living aquatic animals, the lenses fitting into a special arm which can be moved about all over a glass plate. Mayer studied on zoology at Jena and took his doctor’s degree under Ernst Haeckel in 1874. At the Neapolitan Zoological Station, he was promoted from Prof. Dohrn’s assistant to a professor publishing on microscopic technique for zoologists.

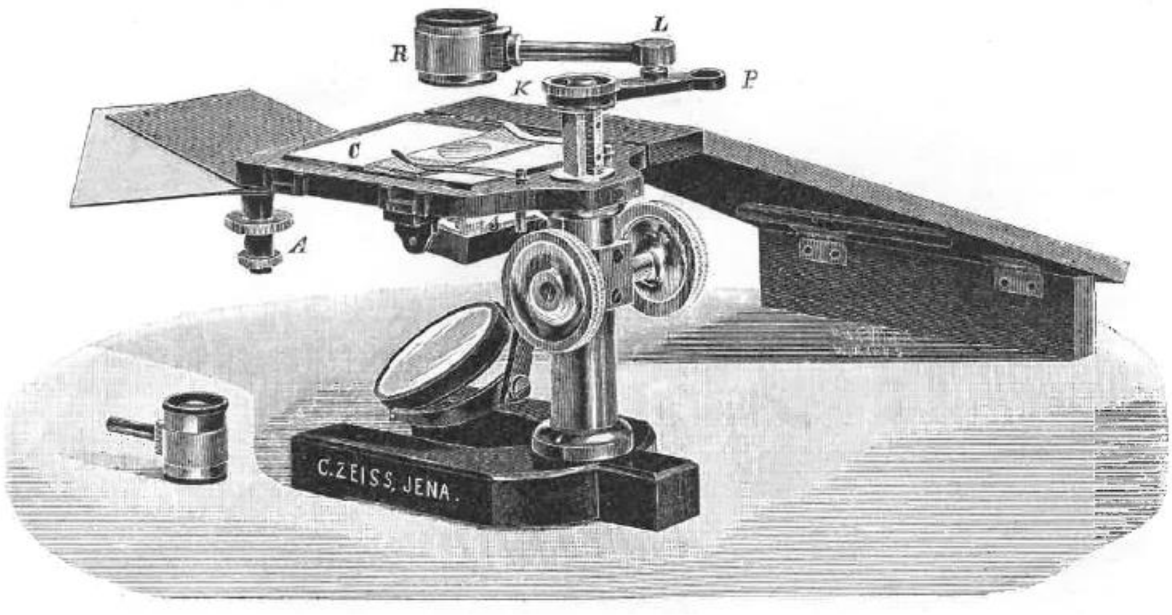



Figure 57 Dissecting Stand I after Paul Mayer [Zeiss, 1891].

A modified version of the first Zeiss microscope - now called Dissecting Stand IV - was offered up to about 1895. Stand IV will be replaced by Greenough's Binocular Stand in the 1898 catalogue.

**Synopsis of Magnifiers.**

| No. | Type | | Magni-fication | Focal distance mm | Visual field mm | Price Mks |
|---|---|---|---|---|---|---|
| 80 | Doublet | a) | 17 | 13 | 4 | 6.— |
| | | b) | 33 | 5 | 2 | 6.— |
| | | c) | 70 | 2.5 | 1.2 | 9.— |
| 81 and 82 | Magnifier | | 10 | 13 | 14 | 4. and 6.— |

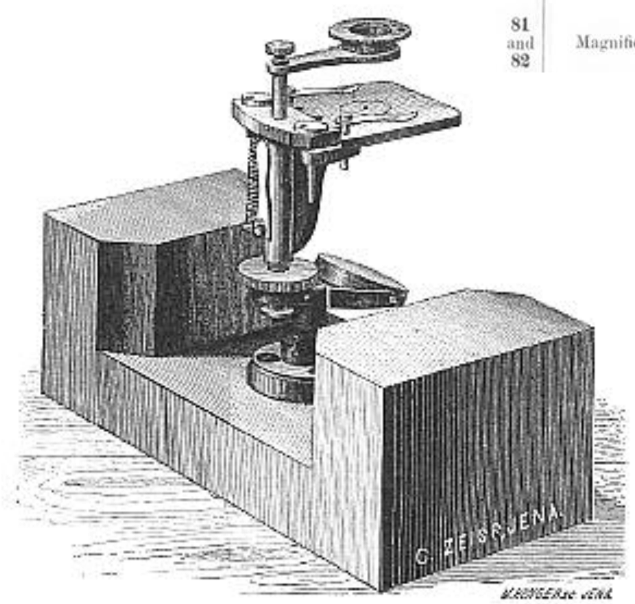


Fig. 63.
Dissecting Stand IV.

| No. | | Marks |
|---|---|---|
| 72 | *Dissecting Stand IV (Fig. 63). Constructed after our well known former model; coarse adjustment by sliding lens holder, fine adjustment by micrometer screw. Concave mirror. | |
| | a) In case on which it screws when in use . . . . . . | 32.— |
| | b) With case and separate foot, with rests for the hands | 34.— |
| | c) Without case, screwed to the foot . . . . . . . . | 25.— |
| | The lenses described under the numbers from 80 to 82 are particularly suitable for this stand whilst Nos. 76 to 79 are not adapted for it. | |

Figure 58 Dissecting Stand IV and Related Magnifiers Inclusive Mark Prices [Zeiss, 1891].

### 19. His "Whole Plan" of Construction

Dr. Czapski's draft [BACZ 1578, 33-36] of his reply on November 17, 1892 let us know:

"Prof. Abbe's calculations for the stereoscopic microscope have been completed for weeks, but they have not yet been carried out. We now hope to be able to take immediate action on this matter. However, we cannot yet give a date for completion."

We learn that Prof. Abbe dealt soon with the optical design of the stereomicroscope by himself and we would think that he was interested in this new approach as sequel of his basic investigations in microscopic stereoscopy (See Part 2/8).

On November 21, HSG replied to Carl Zeiss Esq. [BACZ 1578, 10-11], underlining was done by the Zeiss side:

"I wish if possible to use it (*stereomicroscope*, the authors) <u>next spring beginning not later than March</u> in the study of amphibian ova & embryos. If the model you are now making proves successful with magnifying power of 20X, it would be quite sufficient to begin with, provided you were willing to leave it with use for the spring season, say until the middle of June …"

HSG's desire will be fulfilled at the end of March, but unfortunately, one year later. The lengthy development procedure of a large factory was unexpected and undesirable by our private scholar.

Dr. Czapski wrote to Prof. Paul Mayer at Naples on February 7, 1894 [Flitner, 2000]:

"I also hope, on the occasion of my visit, to be able to show you some other apparatus, the construction of which we are currently working on at the suggestion of an American scholar. There are: First, a binocular dissecting microscope, Secondly, an apparatus to examine small objects - the size of shot grains - from all sides without touching these objects. Third, an instrument that accomplishes something similar in objects whose size requires the use of very strong systems (including homogeneous immersion). As I said, these devices are already in the works and, if nothing goes wrong, they will be ready by the end of March."

HSG was informed on the planned prototype construction of a binocular microscope by Czapski's letter of January 30, 1894. HSG replied to Professor Dr. Abbe on February 12 and argued strongly for his orthomorphic type of construction [BACZ 1578, 47-50]:

"As a preface to what I am about to say I would first remark that any microscope constructed in accordance with my equation **A/a=D** will give stereoscopic vision that is not only orthoscopic but also orthomorphic: now dismissing pseudoscopic effects as irrevalent [sic] stereoscopic vision may still be deficient in orthomorphy in two distinct ways: - 1ly it may be to a greater or lesser content an orthomorphic or even completely so. - in this first case the monocular image is in correct or tone central perspective in each eye, and both the distance of the object from the observer & its depth in space are other not well defined or entirely undefined and the observer is in visual ignorence [sic] of the shape of the object.

Calling **π** the parallax to the base **A** of any point on the object – for choice the nearest point, and denoting by **Δπ** the difference of parallax between such point and any other on or in the object, and denoting by **C** that value of **Δπ** which corresponds to the minimum visable [sic] **Δπ-C** will be a measure of orthomorphic efficiency.

2ly Stereoscopic vision may be antiorthomorphic, in this 2d case the monocular image is in false central perspective, and the apparent distance & depth are both well defined but the shape of the object is incorrectly seen and the observer is in visual error! Calling **F** and **P** linear or rather line magnitudes (since linear is usually used in an algebraic [sic] sense) in the field & normal to it respectively; orthomorphy requires that we have **P/F=1**; put for the sake of brevity; **P/F=**$O_r$ and **1-**$O_r$**=Δ**$O_r$ and **Δ**$O_r$ becomes a measure of the antiorthomorphic effect of any given combination (*See A Note*, the authors).

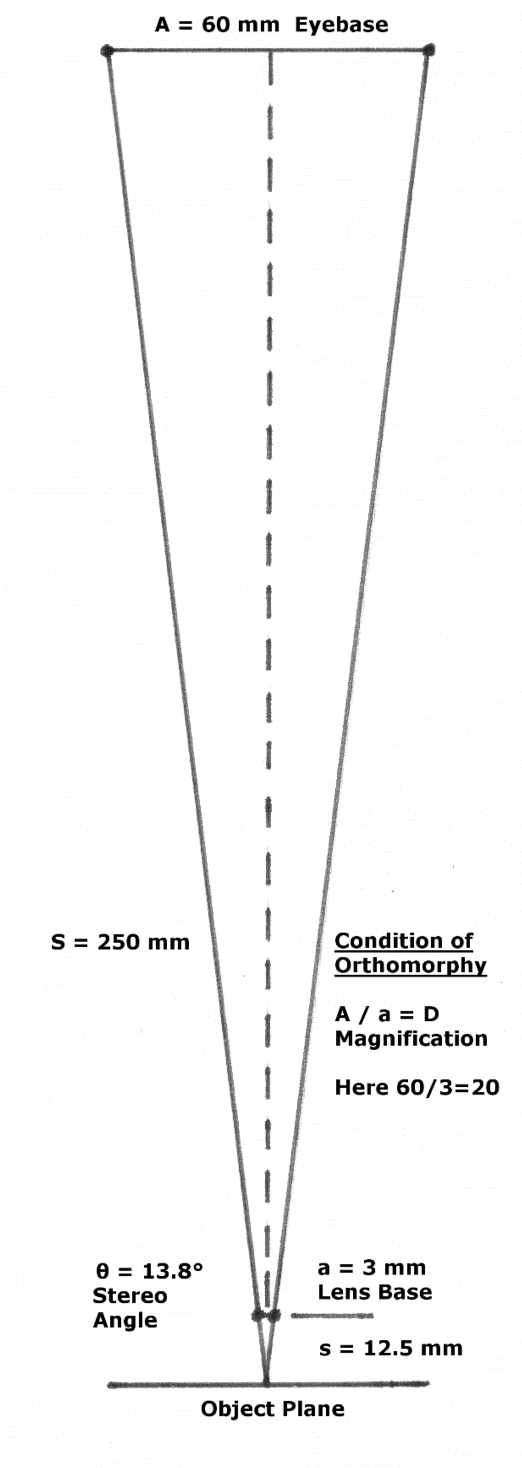
And now I can state the first point I wish to submit for your consideration – In view of the considerable expense of the constructions contemplated might it not be worth while to first compute the values of both **Δπ-C** and **Δ**$O_r$ for a microscope employing only one objective (not one to correspond with each eyepiece) where the two images are given by prisms; in say the following cases 1st for a sphere of ¼mm diameter stereoscopically magnified 40 times – 2d for a sphere of 2mm diameter magnified 20 times – 3d for one of 4mm magnified 10 times and 4th for one of 8mm diameter magnified 5 times. Such a computation would I believe show a marked superiority of a microscope satisfying **A/a=D** over that employing only one object glass; provided of cause that in each case the depth of linear (or line) focus be somewhat greater than that of the corresponding sphere. This opinion is however an empirical opinion based on some seasons work with the Nachet Binocular (used for preliminary manipulations which experience had shown to be, for me, too laborious for common practice when performed with an ordinary microscope) (*See B Note*, the authors) and also on certain statements contained in Dr. Czapski's work on the microscope. Now it might happen that the computations suggested should show 1ly that the deficiencies from orthomorphy of the single objective, prism-using microscope, lie beyond the limit of visual perception. 2ly that they lie inside of such limit but only slightly 3ly that they lie well inside the limit.

In the first case my device would offer no practical advantage and its construction no further interest than a confirmation of the computed result – in the 2d case it would offer a slight advantage but not enough to warrant a great increase of cost & in the 3d case which is what I should expect;

my plan would offer a very great advantage and should be executed in the best form that is not of prohibitory expense. – This brings me to the portion of Dr. Czapski's letter before spoken of but 1st I will relate an expert opinion of a sculpter [sic] friend (*Paul Wayland Bartlett, 1865-1925,* the authors) that has a bearing on this question. Some time ago I took with an ordinary commercial stereoscopic camera (*See C Note*, the authors) & without being able to observe any of the conditions necessary for a rigourous [sic] orthomorphic effect several photographs of a dolphin: (delphinus delphis I think), namely: - one lateral, one dorsal, one ventral, one posterior and one anterior and one oblique. I showed these to a sculptor friend both in the stereoscope and out of it & he told me that with the series & a stereoscope he should feel confident of being able to make a fairly good model of the dolphin but that with the photos alone he could not do so.

Dr. Czapski states in his letter that your house will shortly make the new stereoscopic microscope in two forms 1ly according to my original plan with two objectives, and (*2 ly*, the authors) with the new prisms employing binocular & only one objective. Now I do not quite understand whether the first plan contemplates the integral execution of my first device namely two objectives in each of the twin microscopes composing the apparatus, four in all or only one in each, two in all, & some prism combination. But before the working drawings are made I would say that these are certain practical reasons I will mention which in my opinion militates very strongly in favour of a twin microscope composed of two separate tubes & with an erecting objective in each tube; four in all. The most important is this that with such device the virtual & real objects are both in the immediate neighbourhood [sic] of the intersection of the optic axes and the degree of harmony thus introduced between the senses of touch & of sight would in my opinion very considerably increase the usefulness of the microscope mean used as a working instrument for dissection or other manipulations. This increase of efficiency might well in my opinion make all the difference between an instrument of considerable value for common use & one that could only be used with some difficulty, in about it might perhaps make the difference between a practical & an unpractical device. A second advantage if I am not mistaken would be in the saving of light, as I take it for granted that the erecting prisms etc. would absorb much more light than a second erecting object glass. now [sic] inasmuch as sharp deep images are essential to the useful effect of my device, anything that will increase the light available & thus admit of increased stopping is most desirable (*See D Note*, the authors).

A third advantage is that my plan will admit of varying the angle of optic axes, (implying of course a corresponding variation in length of microscope tubes) to suit different magnifications; and this might prove of value in increasing the range of magnifications that could be usefully used (*See E Note*, the authors); I do not suppose it would be desirable to go beyond 40X. – and I think 20X would be a very useful power. I should choose it if only one be had, but I also think both 10X & 5X would be very useful.




If my whole plan be adapted the magnification of twenty with an angle of 14° between the optic axes and an assumed value of 60$^{mm}$ for **A** would give for **'a'** a value of ~~**12 ½**~~ **3** millimetres [sic] and if the distance from either end of **A** to intersection of Optic axes be taken as 250$^{mm}$ the distance of either end of a from intersection of optic axes would be about ~~**50**~~ **12**$^{mm}$ and a tube length of ~~**somewhere from 180 mm to 220**~~ **about 250**$^{mm}$ (*cancelations and revisions by the addressee,* bold typed by the authors) would be needed."

HSG corrected this in a post card on the same day:

"The value of **a**" should be 3$^{mm}$ instead of 12 ½ $^{mm}$ and "the distance from either end of **a** to intersection of optic axes" should be 12$^{mm}$ instead of 50$^{mm}$ & length of tubes should be about 250$^{mm}$ instead of "from 180 to 220$^{mm}$" (*See F Note*, the authors).

"I will not now dwell upon the advantage of being able to vary the optic axes angle & length of tubes for varying magnifications, as I fear I may have already wearied you with this long letter. I will only add in expressing again my thanks for your kindness in testing this matter that if with doing at all it is worth doing as well as it can be done. the essintial [sic] feature of my device expressed fully by the equation **A/a=D** should be executed in such special form as will – best secure its most practical advantages in an instrument designed both for long continued observation of living objects & for careful & accurate manipulation. – to effect this it is needed that the mechanical accessories in current use & developed to suit a different purpose should give way to new ones designed to meet the wants and in harmony with the construction of the new instrument.

Figure 59 Scaled Sketch of HSG's 20X Orthomorphic Proposal.

Before closing I take the liberty to remind you that I think it most desirable to have the objectives constructed to plunge into the water holding the embryos etc. both because of such slight increase of focal depth as may thus be obtainable (for every little tiles) & still more & most especially to avoid the refraction-caustic distortion that would otherwise ensure (*See G Note*, the authors).

Yours most faithfully Horatio S. Greenough"

**A Note:**

The "**π** … parallax to the base **A** of any point on the object" means the stereo angle. The **Δπ** value is the viewing angle of an object detail and **C** the angle resolution of the eye. All these values are not related to the orthomorphy definition.

HSG demands that the **F** magnitude (meaning an imaged constant distance or the image scale) in the image plane and the analogous **P** one standing perpendicularly to this plane shall be equal in image space. Seen from his application, he wishes the ideal equality of lateral and axial magnification. But he forgets Hastings formula already used in 1892 (See Part 2/10) that the axial magnification is the square of the lateral one. The equality is given only by the helpless 1X magnification. The **$P/F=O_r$** quotient results higher than one in all magnifications above 1X. The **$1-O_r=\Delta O_r$** value shows correctly the negative variation from HSG's expected orthomorphy ideal but indeed it represents the magnification only.

**B Note:**

The binocular and stereoscopic terms were mixed up often in these early days. The provided image depth is not realistic. HSG's train of thought was to show that different sphere diameters could result in the same flat image when they are magnified indirectly proportionally to the sphere diameters:

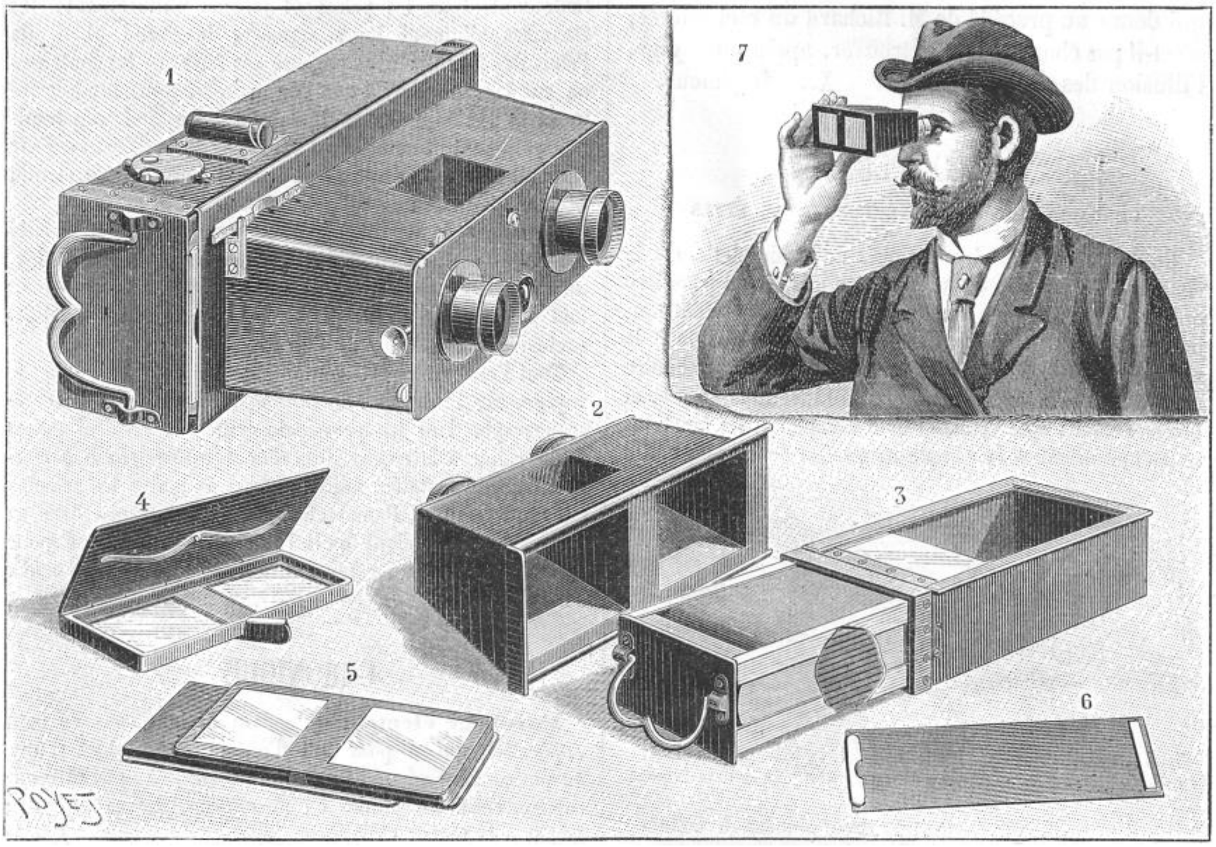
| | **HSG's Example of Binocular Microscope Using One Objective** | | | | **HSG's Orthomorphy** |
|---|---|---|---|---|---|
| **No.** | **Sphere Diameter** | **D Magnification** | **Diameter of Image** | | **Stereo Base by a=60 mm/D** |
| 1 | ¼ mm,<br>1 mm is correct | 40X | 10 mm,<br>40 mm is correct | | 1.5 mm |
| 2 | 2 mm | 20X | 40 mm | | 3.0 mm |
| 3 | 4 mm | 10X | 40 mm | | 6.0 mm |
| 4 | 8 mm | 5X | 40 mm | | 12.0 mm |

Does this simple example prove the "superiority of a microscope satisfying **A/a=D**"? The double microscope provides an image pair that the spheres can be seen spatially. Their differences in real size are also compensated by corresponding magnifications. The HSG's formula gives the stereo base by **a=A/D** (**A**=60 mm) which grows by the same 2 modulo like the sphere diameters.

If the working distances would grow in the same manner then the stereo impression could be always the same, one due to similar geometry of vision lines in object space. HSG's positive experience in Nachet's Binocular is correct but due to its fixed structure which is not varied by the orthomorphic demands. Drawing any conclusion from Nachet's Binocular to the orthomorphic microscope is inappropriate.

**C Note:**

HSG used the recently launched Richard's Vérascope stereoscopic camera. In November 1895 HSG will ship to Dr. Czapski a "Virascope" camera and point out that it was published by "Revue générale des sciences pures et appliquées" (firstly in 1894, pages 649 – 653).
The Parisian Jules Richard (1848-1930) started the first models of his successful and extensive camera series in 1894, already patented in 1893. He introduced a lightweight metal body, smaller photo plates and the twice function as stereoscopic camera and viewer resulting in the first handy and budget-priced stereo photo equipment.




1. Apparatus mounted for obtaining a photo. – 2. Outer casing. – 3. Plate magazine. – 4. Frame for printing positives. – 5. Support for positive plates. – 6. Curtain of plate magazine. – 7. Stereoscope-mounted device

Figure 60 Richard's Vérascope Stereoscopic Camera [La Nature, 1894] and Legend Translated by the Authors.

**D Note:**

HSG mistakes Dr. Czapski's intention surely in his "make the new stereoscopic microscope in two forms" phrase. One prototype construction will include two microscopes each equipped with an objective, a Porro-Abbe prism and an eyepiece but not with HSG's second objective for image erection.

HSG adds a new aspect relating to stereomicroscope's application in dissection and manipulation: "the degree of harmony thus introduced between the senses of touch & of sight" which becomes a further cause to reject the Porro-Abbe prism because of its optical axis offset. The alleged larger light loss of prism is an already known criticism.

**E Note:**

The "varying the angle of optic axes" results from the **A/a=D** geometry in getting more than one **D** magnification. But its practical solution would be extravagant, e.g. the tilting axis of both microscopes has to include the intersection point of their optical axes. There the object is laying and so no spindle is allowed. The "tubes might be practically replaced by pyramidal soufflets" (*French for bellows*, the authors) is written by HSG to enable the "corresponding variation in length of microscope tubes" and "centering would require an outside guiding metallic rod.- or possibly the same effect might be had by telescoping tubes provided the largest and shortest be made conical" [BACZ 1578, 52-53].

**F Note:**

While the assumed **A**=60 mm is a realistic measure HSG gives no solution to master the span of the individual eye bases. The **a**=3 mm base causes a front lens diameter only below this measure and less than 0.2 numerical aperture or f/5 focal ratio.

**G Note:**

Firstly HSG proposes "the objectives constructed to plunge into the water" which is a good point in stereoscopic investigation of his marine organisms. In 1898 the well-nigh apochromatic PI objective (f=25 mm, WD=36 mm in water) was introduced under the designation of the Plankton-Searcher. In 1902 a PI objective pair was launched for stereoscopy [Zeiss, 1902].

HSG's "still more & most especially to avoid the refraction-caustic distortion" further argument is taken up by Leica Microsystems today:

"With the Leica Plan Apo 2x Corr (*CMO objective*, the authors), even thick embedded samples or samples immersed in a deep aqueous solution (5 mm) can be imaged with little or no (*spherical*, the authors) aberration" [DeRose, 2015].

On February 16, HSG lets us know that Prof. Abbe replied to him soon even though his letter is missed:

"I understand from a letter written to me by your Prof. Dr. Abbe that a given magnification with given defination [sic], or resolving power, requires a given aperture … I say all this because I understand from your Prof. Dr. Abbe that he considers a practical advantage of my plan as possible" [BACZ 1578, 59-60].

HSG had sent to Prof. Abbe a letter of four sheets written on both sides. Two days later, eight of such sheets were directed to Dr. Czapski [BACZ 1578, 51-58]. The authors will quote chiefly the thoughts on the stereomicroscope:

"I have delayed for some time answering the remainder of your Dr. Czapskis letter of January 30th ult. both because I wished to carefully & as fully as may be consider the portion I have not hitherto answered and also because I wished to have certain passages retranslated to me: this was kindly done yesterday afternoon by our demonstrator Mr. Caullery (*Maurice Caullery, 1868-1958*, the authors) & I will now answer the various matters submitted to me to the best of my ability. – Before proceeding further I will make the following statement because it has an important bearing on much of what is to follow. – Simplicity being a criterion of excellence, should whenever possible, be maintained in essentials even at the cost of increased complexity in accessories provided of cause that such cost is not prohibitory – Your large stand no 1a (*See Part 3/11,* the authors) is a good example of this principle, the essentials, in this case an efficient degree of harmony between the special sense of light and the sensation of muscular effect, are well maintained by means of the mechanical substage; and working with it, investigation involving long continued & both very minute and accurate manipulation can be made not only with comfort but with positive pleasure to the operator **-** Now this is accomplished at the cost of the increased complication of the substage of which the money value is represented by a difference of 100 MK or a third of the price of the plain stage no 1. When I purchased your microscope I had never used a mechanical substage but decided to pay the increase of price on the strength of the recommendation contained in your cataloge [sic] & I consider that the money was exceedingly well spent!

You ask whether I wish for more than one magnification in my form of the new stereoscopic microscope?that [sic] will depend upon the character of the construction you have decided upon: I will repeat that the decision in this matter both as to mechanical and optical construction rests entirely with yourselves; but I deem it of importance that the form contemplated by me be fully executed; if so the use of the new microscope will be, to a good approximation pies, practically equivalent to the possibility of giving to the object studied an actual pure 3 dimensional dilatation of coeficient [sic] equal to the magnification employed and moreover of so dilating it in situ, so that both the virtual & actual object lie in the immediate neighbourhood [sic] of the intersection of the optic axes, and this last feature I deem, as explained in my recent letter to your Prof. Dr. Abbe of very great importance to the practical efficiency of the new microscope as a working instrument; for observation alone the first mentioned feature expressed by my equation **A/a=D** is quite sufficient.

If your construction contemplates a fixed angle of 14° between the optic axes I am enclined [sic] to think that a single magnification of 20 will be best; but I should add that this will in my opinion seriously interfere with the practical value of the instrument and that one so constructed appears to me to offer small promise of future commercial success. My own idea is that the new instrument should admit of magnifications of from 5 to 40 both inclusive, using only four in all the other two being 10 & 20 respectively, of all these I consider 20 of the greatest value & next both 10 & 5 to an equal extent & 40 still very useful but decidely [sic] less so than the others. –

In my opinion the 20X should be the$1^{st}$ executed but the construction adapted should admit of the addition of the others without the need of making any alterations in the construction mounting. Now for the smaller powers there would, I take it for granted, be available a relatively much increased depth of focus or in other words a considerable increase in the value of the ratio depth/field (assuming as the minima of a good performance for 20X a linear field of $5^{\underline{mm}}$ and linear focal depth, including accommodation, of at least $3^{mm}$ for good well defined images) & …

… - calling for shortness **S** the distance from either end of **A** to intersection of optic axes, **s** the corresponding distance for little **a**, a: and **θ** the angle between optic axes (*See also Fig. 59*, the authors). I think the followed may be considered as the extreme limits of useful variation. Magnification 5X i.e.

| | | |
|---|---|---|
| | ( | **D**=5 **θ** =6°30’ **S**= $500^{\underline{mm}}$ **s**= $144^{\underline{mm}}$ **a**=$12^{\underline{mm}}$ **A**=$60^{\underline{mm}}$ |
| offhand | ( | ------------------------------------------------------------------------ |
| approximations | ( | **D**=40 **A**=$60^{mm}$ **a**=$1½^{mm}$ **S**=$140^{mm}$ **s**=$3½^{\underline{mm}}$ |

these are the two extremes (*See H Note*, the authors), 20X would require tubes of nearly $250^{\underline{mm}}$ at ang. **θ**=14° and other dimensions as stated in my postal card to you. For 10x an intermediate value of about **θ**=9°or perhaps a little less might be taken and other dimensions accordingly.

Now I fear that the foregoing will appear to you utterly preposterous and fantastic: it is so completely at variance with customary Micrographical practice! but I see no other way that appears promising towards giving effect to the essentials of my plan; and if these essentials be not practically executed the instrument would in my opinion be little better than a laboratory curiosity having little more than a purely theoretical interest! … But the hearty cooperation you are now giving me & the money that you are spending toward the execution of my technique without any prospect of other than a remote future profit have after some meditation convinced me that I should lay my whole plan before you so far as the present technique is concerned and I will now do so. I do this the more readily there is in my opinion a possibility, through a somewhat remote one of the commercial success of a Working Laboratory specially organized for the carrying out of my plan: this may be described briefly as the systematic synthetic visuation [sic] of acquired results. - it is of my certain knowledge that this system was under contemplation for one of most important morphological Laboratories in America & I was told about it by the director when last I went home in 1892.


Figure 61 Collins' Lawson Microscope (London, about 1870) as Example for Early Binocular Dissecting.

The plan has perhaps been carried out, I do not know – the proposed method of execution was however, in my opinion less complete than that contemplated by myself, and consisted in the systematic making of morphological, <u>solid</u> demonstration models by an artist specially employed for the purpose & working under the immediate supervision of the director (*See Part 3/15 for origin by Prof. His*, the authors); now my plan is I believe better, for I would in addition to this make a systematic use of <u>pairs</u> of <u>plotted</u> series section reconstructions, plotted in central projection according to a suitable angle of intersecting optic axes, and to be looked at in a stereoscope satisfying my equation **A/a=D** for the case when **A=a  D=1**: **-** and adjustable within requisate [sic] limits to any desired value of the angle **θ** ...

I will if you see fit forward to Professor Dr. Whitman drawings and estimated price of the new Microscope: he wrote to me that he should give you an order for it …

I hope you will, in the drawings of new 2 obj. Microscope, make provision for an attachment adapting it for taking Stereoscopic Views; the omission of this future would very seriously impere [sic, impede] its value in my opinion, and your published Microphotogravures convince me that excellent stereoscopic views can be made under the magnifications contemplated! …

On the 1st of March I shall be pleased if you see fit to make a prepayment … sending you draft for such sum as I may have available which will I think be between £50 & £80 as the extreme limits.

nein, wir danken (*no, we thank*, note of addressee translated by the authors)

Awaitin [sic] your reply I remain gentlemen

yours faithfully

Horatio S. Greenough

**H Note:**

While HSG carried out the 20X version only to Prof. Abbe now the full optical and mechanical extent becomes visible: The transmission distance varies between 500 and 140 mm and the stereo angle between 7° and 25°! Please see the E Note for his mechanical proposals.

On March 8 HSG summarized his demands in a letter to Dr. Czapski:

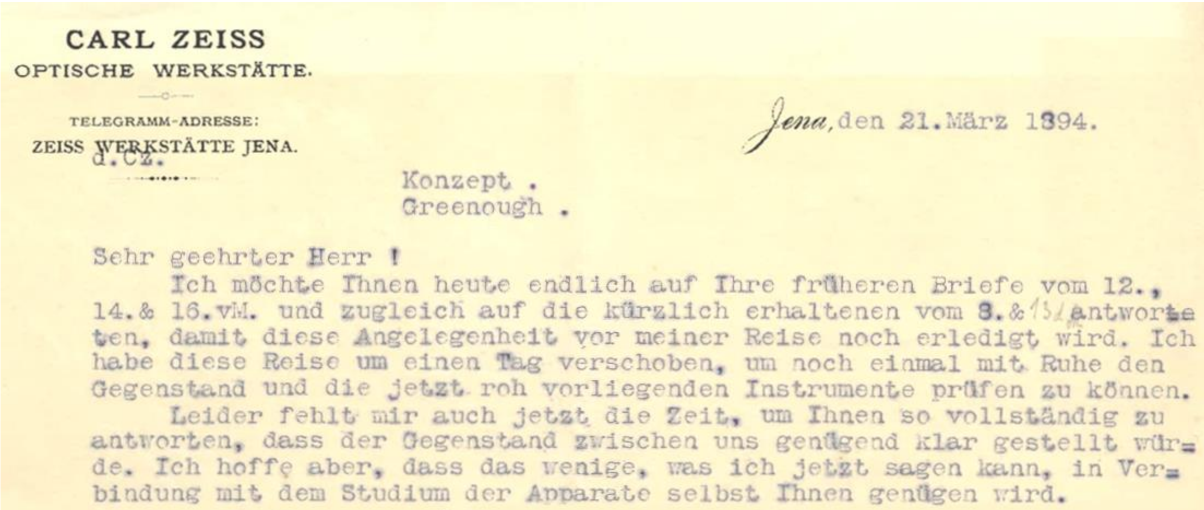
“Your kind favour of Mch. 6th is this day received & contents noted.
When next you write would you be good enough to do so in English as my knowledge of German is unfortunately so limited that I have been obliged to have your letter translated to me.

I am very glad that you intend to give my letters to your firm & to your Prof. Dr. Abbe careful consideration before further proceeding with the construction of various apparatus under contemplation. – It may perhaps render the study of my letters easier if I here call your attention briefly to the essential points!

1st the key note to all I have said lies in this sentence contained in one of my letters to your firm – ‘Simplicity being a criterion of excellence should be maintained in essencials [sic], whenever possible, even at the cost of increased complication in accessories: provided that the increased cost be not prohibitory!’ 2d the substage of my proposed orthomorphic microscope is this: the practical equivalence to the performance upon the object to be studied of an operation of pure dilatation in situ! 3d in the rotating capillary apparatus, the obtaining of a simple rotation about a horizontal axis! …” [BACZ 1578, 62]

## 20. His First Judge on the Stereomicroscope Prototype

On March 21, 1894 Dr. Czapski described all three finished prototypes in German [BACZ 1578, 64-66]. These three concept pages are the earliest typed * ones of this correspondence. Czapski responded sensitively to HSG's expectations.



CARL ZEISS
OPTISCHE WERKSTÄTTE.

TELEGRAMM-ADRESSE:
ZEISS WERKSTÄTTE JENA.

Jena, den 21. März 1894.

d. Cz.

Konzept .
Greenough .

Sehr geehrter Herr !

Ich möchte Ihnen heute endlich auf Ihre früheren Briefe vom 12., 14.& 16.vM. und zugleich auf die kürzlich erhaltenen vom 8.&13. antworten, damit diese Angelegenheit vor meiner Reise noch erledigt wird. Ich habe diese Reise um einen Tag verschoben, um noch einmal mit Ruhe den Gegenstand und die jetzt roh vorliegenden Instrumente prüfen zu können.

Leider fehlt mir auch jetzt die Zeit, um Ihnen so vollständig zu antworten, dass der Gegenstand zwischen uns genügend klar gestellt würde. Ich hoffe aber, dass das wenige, was ich jetzt sagen kann, in Verbindung mit dem Studium der Apparate selbst Ihnen genügen wird.

Figure 62 Head of Dr. Czapski's Concept of March 21, 1894 [BACZ 1578, 64].

"Concept . / Greenough .

Dear Sir!

Today I would like to finally thank you for your earlier letters from the 12th, 14th and 16th of previous month and at the same time respond to the recently received 8th & 13d of the month so that this matter will be dealt with before my trip. I postponed this trip by a day so that I could calmly examine the object and the raw instruments now available.

Unfortunately, I still do not have the time to answer you so completely that the subject between us would be made sufficiently clear. However, I hope that the little I can say in connection with the study of the apparatuses will be enough for you.

As for the capillary rotation apparatus …

---

* The typewriter came surely from the U.S. because it was not yet manufactured in Europe. It was a common tool in North America since about 1885.

In response to an inquiry at the end of your letter dated 14th of previous month, I would like to remark here that we do not make any prepayment or any other financial guarantee. We are interested in the devices that you have proposed to us, and we are therefore happy to bear the risk of success. If we did not believe in these devices, you can be sure that we could not be persuaded to carry them out for any amount of money. So I ask you to refrain from this point first.

We implemented the prism rotation device …

Greenough II .

We will send you the orthomorphic microscope, also in raw condition. We urge you to approach the exam with as little prejudice as possible. We have taken your wishes into account when executing the same, as far as possible:

1.| with the least possible mechanical and optical means, &

2.| we ourselves believe as far as to be able to take over the responsivity for the construction. An even more complete consideration of your wishes would sometimes involve major technical difficulties and thus costs and a great loss of time. On the other hand, we could not convince ourselves of the correctness of your statements and did the job to the best of our own knowledge.

As I said at the beginning, it would go too far if I discussed each of the points you mentioned respectively wanted to justify the embodiment we chose for each one. I just want to briefly highlight a few points.

1.| We give effect to the image reversal by means of prisms and not in the usual way through an image-inverting dioptric system. The latter would have to consist of at least 2 | not as you say of 1 | lenses. We would have had to calculate the same in particular and who knows when we would have had to do so. In my opinion, the image reversal using prisms is hardly more fading than by 2 lenses. It was also immediately executable. Thirdly, it offers the extraordinary advantage that it offers the possibility of changing the ocular distance | by rotating the prism boxes around the eccentrically located tubes |. Just how important such an adjustment to the observer's eye distance is, we have just seen through numerous experiments (*to the field glass,* the authors) in the past few years. It also has the advantage that the eyepieces are easily interchangeable and that objectives of different strengths can be attached readily, if these objectives are only appropriate. I believe that these advantages are significant.

The height of the binocular end above the object is only about 22 cm instead of 25. In addition, the image is shifted back by a few cm (*both effects caused by the Porro-Abbe prisms*, the authors). But you will surely convince yourself that despite these deviations from your plan, the harmony between feeling and sight does not appear in the least disturbed. At least that was how it seemed to me in my experiments.

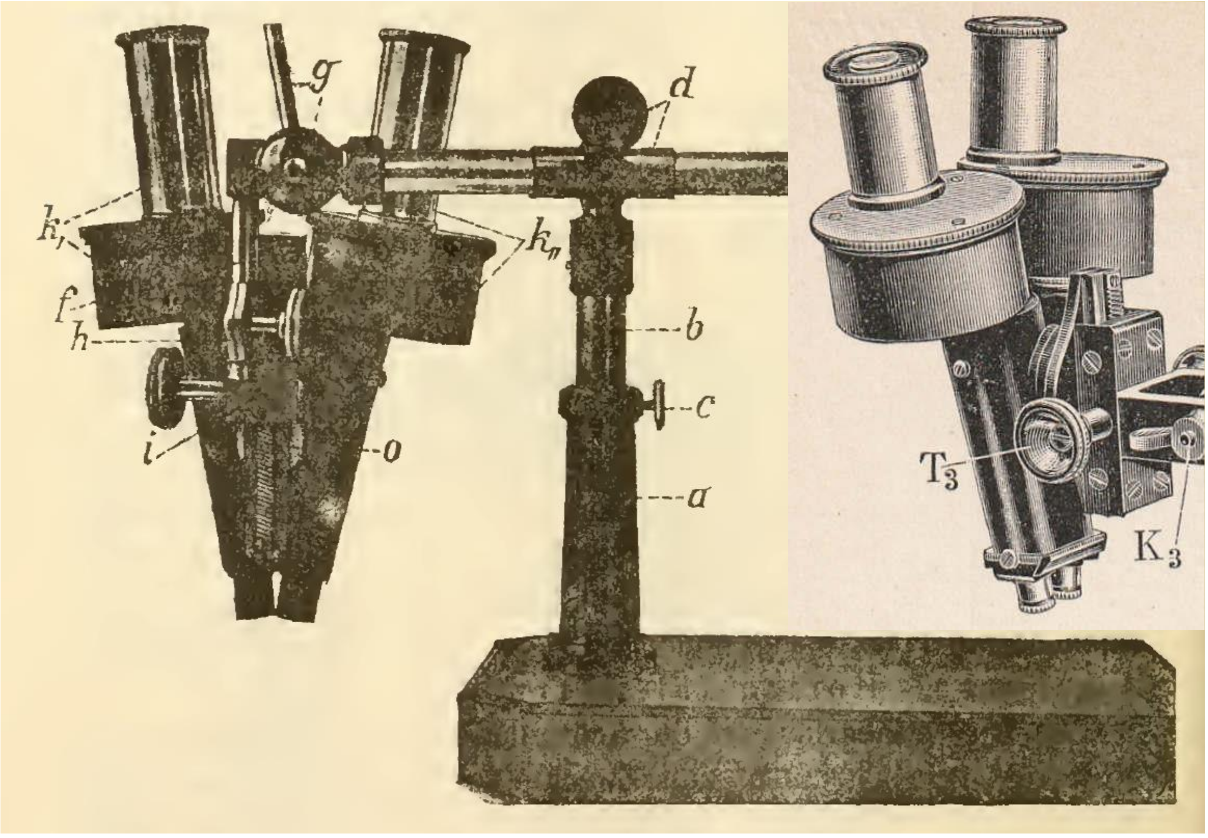



Figure 63 Boom Stand with Prototype [Braus, 1895] and Commercial Version [Zeiss, 1898] for Comparison.

The objectives that we have now attached are unfortunately somewhat strong. With the weaker oculars you give about 20 times, with the stronger ones about 25 times (*See J Note*, the authors). Using even weaker eyepieces is not convenient because the field of view would then be even more reduced. However, we can easily supply you with much weaker objectives later, so that you can go down at least 10 times with the magnifications.

It seemed to us an important condition for the construction of the instrument that the optical axes of the two tubes intersect exactly where the foci of the two objectives lie. Since the position of these foci varies with the use of different oculars and also with the visual range of the observer, we have made each of the objectives somewhat variable for itself. In fact, it had to be taken into account that the two eyes of the same observer are mostly different (*See K Note*, the authors). The front focus, however, is the point of the axis that is conjugated in the optical system: eye + microscope in relation to the retina.

Greenough III .

However, the experiments seem to show that the focus is not very sensitive. However, the facility that has been found to be very useful from another point of view. One could, at least for me, make it easy to adjust one objective to the upper parts of an object and the other to the lower parts. In binocular vision, both images are then sufficiently combined with each other (*used by FusionOptics™ of Leica Microsystems,* the authors) and you have the advantage of a depth effect, which is approximately equal to the sum of the depth effects of each individual microscope. But if you want to see a certain point of small depth with very sharp plastic, then it is indeed important to focus both objectives exactly on the same point.

We had planned another small device on the objectives, which should serve to fulfill your main wish: the orthomorphy of the image. We have made a number of cones that can be screwed onto the threads of the barrels. These cones end down in narrow diaphragms. This diaphragm firstly increases the depth of vision and for this purpose you will have to provide diaphragms in any form. Furthermore, your equation: **A/a = B** will be satisfied. Because, of course, the middle of diaphragm becomes the center of perspective for the image. You wanted us to do experiments in this direction. We have done this and we would like to give you the opportunity to convince yourself, which is why we are also sending you these diaphragms. The result seemed completely negative to us.

I ask you once again to approach the examination of the microscope without prejudice. I am prepared from the outset that changes will still be necessary here and there. That is why we send you the instrument in raw condition. So that the depth effect could be varied, I would suggest to attach so-called rotating diaphragms to the two tubes or to the objectives themselves: discs with diaphragms of different sizes, rotatable around a point outside the optical axis.

Since I will probably only be returning in 4 weeks (*See L Note*, the authors), it has taken so long to answer this letter. So you can do a few experiments with the instrument at your leisure.

I would ask you once again not to consider the deviations from your plan that we have made to be arbitrary, but to be the result of our best conviction.

With the best recommendations Respectfully”

This letter gives the authentic info on the stereomicroscope prototype but neglects some technical details. The authors guess that the paper by Dr. Hermann Braus (1868-1924) and Dr. Leo Drüner (1870-1940), medicos at Jena, deals also with the prototype because it was published already in February 1895, earlier than that of the commercial stereomicroscope itself:
“The stereoscopic effect achieved with this instrument compared to the monocular one proves to be so advantageous for the preparation with the same own stronger magnification that it is absolutely preferred” [Braus, 1895].

**J Note:**

The design is indicated by Braus and Drüner [Braus, 1895]:
"The two tubes converging to a point about 25 cm from the eye of the observer are cast in one piece from aluminum bronze. The two lenses correspond to $a_2$ (*f=35 mm achromat*, *not interchangeable*, the authors) of the Zeiss catalog and have been given a special mounting, so that if the eyes are different, an adjustment for each of them can be made … The magnification is / with eyepiece I – 21X / II – 26X / III – 38X / by ca. 25 cm image distance … The deviation of our numbers from the magnifications given for … $a_2$ in the Zeiss catalog can be explained by the extension of the path of the rays associated with the insertion of the image-reversing eyepiece".

The 1891 catalogue states the $a_2$ magnification (See Fig. 41of Part 3/14, HSG owned $a_2$ already) with Huygenian eyepiece 1 – 11X / 2 - 16X / 3 – 23X. This simple low-power achromat could be used on larger English stands (10 inch tube length) without appreciable loss of image quality [Zeiss, 1891] and all the more on prototype. Dr. Czapski hides the cause of the longer tube length than the common 160 mm between the lens-flange faces of objective and eyepiece. His "unfortunately" term may mean that this mechanical tube length was not planned. It seems that the difference of mechanical and optical path length through the prisms was considered twice: At first by the optician and at second by the mechanic.

Since 1868 the objectives were calculated by Prof. Abbe and sketched by him or his assistant. Astonishingly, a layout on the drawing-board has been plotted by the engineer Max Berger (1859-1937) firstly in the nineties. In 1893 he founded the design office and fought for modern technical standard and against the old practice of the "gifted hands". R. Georg Orth (1869-1945), the first academic engineer and the third collaborator with Berger, wrote on the designer reputation at that time:
"In general, the design office throughout the factory was initially called "Zeichensaal" (*German term for drawing room*, the authors). Every member of the business who stood apart assumed that the gentlemen in the drawing room only made drawings of the instruments and apparatus made in the workshops after they were finished" [Orth, 1944].

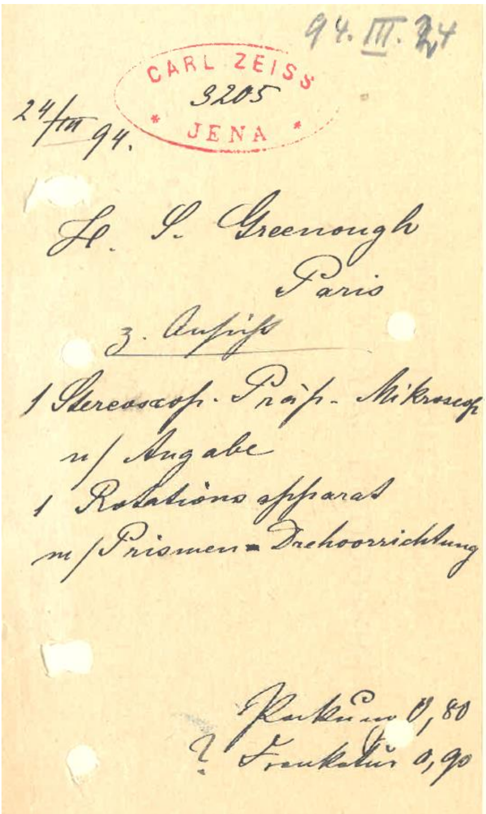
**K Note:**

Dr. Czapski wrote: "… we have made each of the objectives somewhat variable for itself. In fact, it had to be taken into account that the two eyes of the same observer are mostly different." HSG had noted before: "I have serious reasons for thinking that stereoscopic vision, especially with Optical instruments is frequently defective both from astigmatism [sic] & from unequal focal adjustment of the eyes … to adapt to the Orthomorphic microscope, suitable lenses above the eyepieces for properly equalizing [sic] the sight of both eyes" [BACZ 1578, 59].

Both proposals are expensive eye adaptations but HSG's seems the perfect one due to correcting of most ocular defects. Today this job is done by the contact lenses or the eyepieces with high eye point for the spectacle wearers. A focusable eyepiece is common now for astigmatism-free observers but in those days this was used only together with a reticle in a so-called measuring eyepiece.

**L Note:**

On April 05 Dr. Czapski wrote from Naples that he will visit Rome. On May 12 he was back at home and thanked Prof. Mayer for his hospitality [Flitner, 2000].


94. III. 24
CARL ZEISS 9205 JENA
24/III 94.
H. S. Greenough
Paris
z. Ansicht
1 Stereoscop. Präp. Mikroskop
n/ Angabe
1 Rotationsapparat
m/ Prismen-Drehvorrichtung
Packung 0,80
? Frankatur 0,90

*94. III. 24*

*CARL ZEISS JENA / 9205*

*24/ III 94.*

*H. S. Greenough*

*Paris*

*__on approval__*

*1 [pc.] Stereoscop. Dissect. Microscope*

*comes up to specification*

*1 [pc. Capillary] Rotating Apparatus*

*[1 pc. and "with" is incorrect]*

*with Prism Rotating Device*

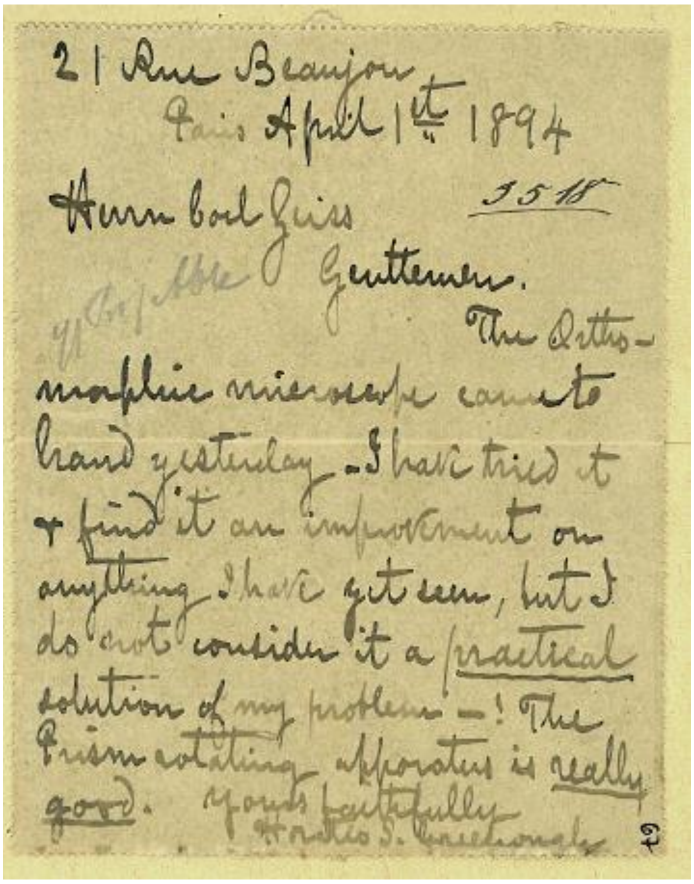
*Packing 0.80*

*? Postage 0.90*

Figure 64 Zeiss Advice of Dispatch of March 24, 1894 [BACZ 1578], Translation and Notes in Brackets by the Authors.

The shipment of the three prototypes to Paris took a week and HSG's first judge was given on April 1. On April 18 eight diaphragms were shipped concerning the creation of orthomorphy on the stereomicroscope.

In those days the Jena town had a population of about 15,000 [Lange, 1993] and was located at Saxe-Weimar-Eisenach Duchy under the reign of the liberal art lover, Duke Charles Alexander (1818-1901). In 1860 he founded the Saxon Art School in Weimar, a root of the later Bauhaus art school.

*21 Rue Beaujon*

*Paris April 1st 1894*

*Herrn Carl Zeiss* <u>*3518*</u>

Hr. Prof. Abbe

*Gentleman.*

*The Ortho-morphic microscope came to hand yesterday. I have tried it & find it an improvement on anything I have yet seen, but I do not consider it a <u>practical</u> solution of my problem - ! The Prism rotating apparatus is <u>really good</u>.*

*Yours faithfully*

*Horatio S. Greenough*

Figure 65 HSG's Folding Postal Card of April 1, 1894 [BACZ 1578, 67].

Why was HSG dissatisfied with the stereomicroscope prototype? Firstly, he missed an exact construction corresponding to his formula, the second objective for image erection and the straight vision lines between object and eyes. Secondly, the focal depth was about an eighth part only of his demand: "… the minima of a good performance for 20X (*should be*, the authors) a linear field of 5$^{mm}$ and linear focal depth, including accommodation, of at least 3$^{mm}$ for good well defined images" [BACZ 1578, 52].

In the following months HSG gave no further comments on the prototypes. On July 4 he "expect(*s*) soon to leave Paris for the remainder of the summer" [BACZ 1578. 72]. He summarizes his activities in letter to his Bostonian friend Lowell on September 5 [Harvard 13/30]:

"My dear Lawrence – your kind letter of July 29th together with Prof. Langley's paper (*Samuel Pierpont Langley, 1834-1906, American aviation pioneer,* the authors) on the 'Internal work of the wind' reached me a few days ago …

Casimir Péner's (*Jean Casimir-Périer, 1847-1907*, the authors) election as President is I think a very good one …

Since I left home in 92 most of my work has been directed toward certain matters of technique & thanks to the cooperation of the Carl Zeiss house of Jena some results are already attained. The purpose of the different apparatus is for the better study of whole solid objects under the microscope – for objects from 1/10 to 8/10 millimetres [sic] of extreme diameter. I have used a modification of a device of Dr. Chabry the objects are introduced into a capillary tube which is placed in the same liquid as that inside of it & the object are then studied with an immersion object glass, - living objects must of course be studied in water but a good result is already in this case, with preparations in oil of cedar and an oil of cedar immersion object glass the result is still better the glass I have used having much more nearly the same index of refraction as oil of cedar than as water. The Zeiss house have in view the manufacture of capillary tubes of the same index of refraction as oil of cedar to two decimals pies & this should be practically perfect: but I do not know whether it will ever be carried out. the [sic] tube is rotated on its own axis under the microscope by special apparatus & this last still demands some improvement though already good.

For the study of Bactracian (*batrachian*, the authors) eggs and embryos and other small objects I have adopted a special 'Prism rotating apparatus' by means of which the object can be seen from above, below and laterally in any direction the rotation being about a vertical axis – the objects are studied with a special 'orthomorphic microscope' to give an erect stereoscopic picture in true perspective: but the microscope now is use is only a makeshift & it is still uncertain whether the Zeiss house will be able to give full practical effect to the equation upon which the orthomorphic effect depends."

One year later, the authorized officer of the Carl Zeiss Company, Max (Wilhelm Conrad) Fischer (1857-1930) ordered glass tubes for oil and water immersion from the Schott Company [BACZ 1578, 85].
Fischer had followed on Roderich Zeiss (1850-1919), the first son of the factory founder, as commercial manager in 1890 and became member of the board In 1895 [Stier, 1961].

## 21. His Making New Contacts

On April 22, 1894 HSG replied on Czapski's letter of April 20 and introduced Dr. Frédéric Félix Auguste Wallerant (1858-1936):

"I am leaving Paris in a few days for a vacation, but My [sic] friend Professor Wallerant Laboratoire de Geologie Ecole Normale Superieure, will attend to my affairs & you may write to him as to myself" [BACZ 1578, 70].

The French and Catholic geologist and crystallographer was lecturer with the same ENS department as the zoologists and author of three general works on mineralogy and crystallography [Sarjeant, 1980].

HSG tried to profit from Wallerant's mathematical tools and his knowledge on optical crystallography acquired by the polarization microscope. HSG wrote in following:

"Since I last wrote to you I have carefully reexamined the problem of Orthomorphic stereoscopy from an optical as well as a geometrical point of view. – I have, by a method suggested by Hamilton, treated the problem as an invariantive [sic] one, depending upon the Congruence of three distinct potentials …" [BACZ 1578, 70].

The Irishman Sir William Rowan Hamilton (1805-1865) worked in both pure mathematics, and mathematics for physics, and made important contributions to geometrical optics and classical mechanics. HSG had not caused any enthusiasm among his partners with Hamilton's theory because

"... in fact, the researchers who have recently been particularly concerned with the further development of geometric optics have too little opinion of Hamilton's considerations by they think it is hopeless to gain new knowledge in this way. So we read e.g. in the recently released, edited by the scientific staff of the optical workshop at Carl Zeiss and edited by M. v. Rohr published works on 'The generation of images in optical instruments from the standpoint of geometric optics', Berlin 1904 on page 22f on Hamilton's theory: The difficulties become insurmountable in the practical application of these teachings. So far, the characteristic function has only been successfully set up in the simplest of cases, which are either meaningless in practice or for which it has long since found the simplest solution in a more specific way" [Blanckmeister, 1904].

HSG went on vacation to see his Sister and Brother-in-law at "Val de Rance, Par Dinan, Côtes du Nord" meaning our day's Vallée de la Rance, the mouth area of the Rance river near the mediaeval Dinan town in Brittany. Here HSG wrote on May 16:

"I have by this mail requested Profesor [sic] Wallerant not to send you the drawings I left with him as I strongly suspect that I have made some errors" [BACZ 1578, 71].

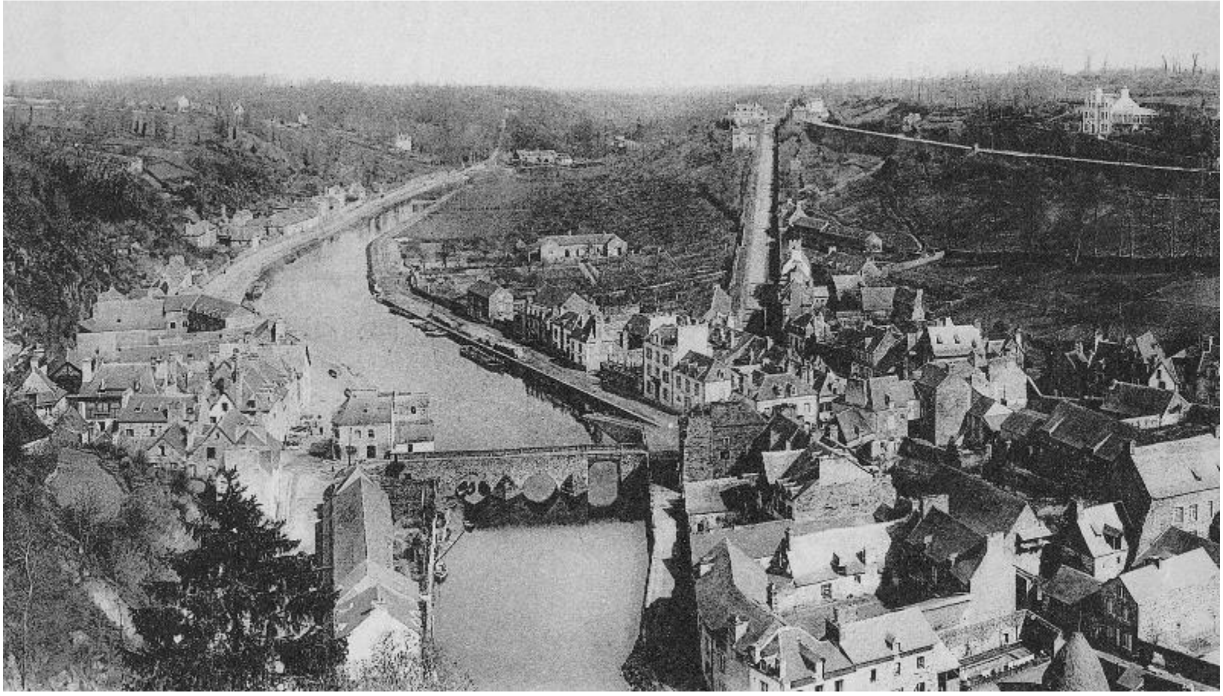


Figure 66 Port of Dinan on Rance River in ca. 1910 (1168 Post Card by ELD Editor).

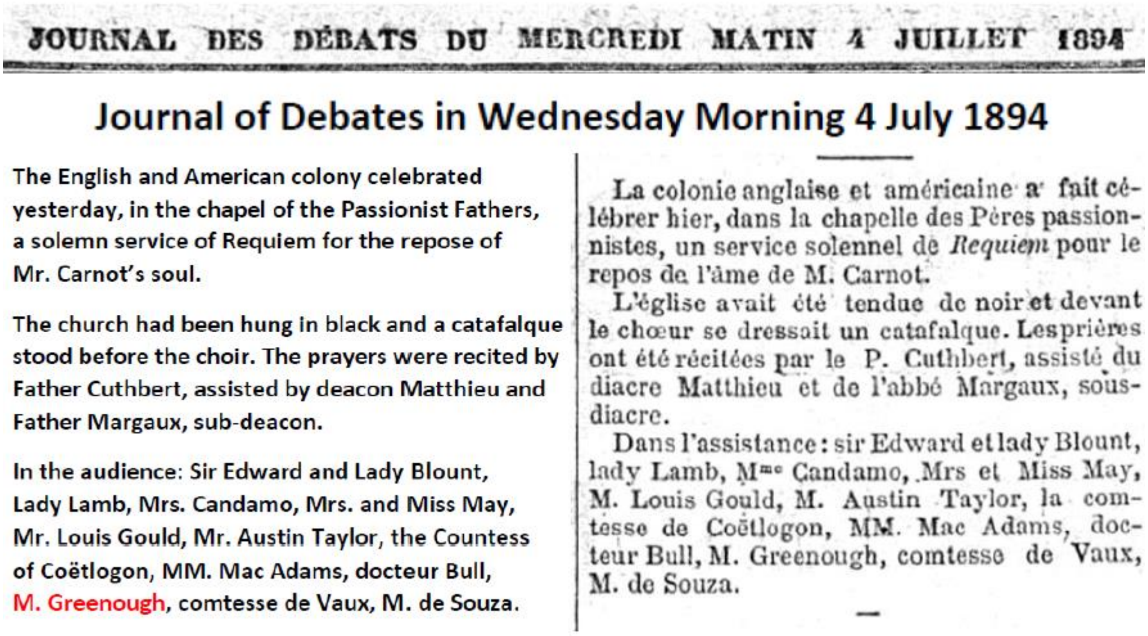
HSG jointed the anglophone Catholic parish of the Saint Joseph's Church run by the Passionist Fathers. The earliest indication may be in a letter dated April 11, 1894 showing HSG's signature including his Mauritius confirmation name (See Fig. 13 of Part 1/6). Another reference comes down on the occasion of murder of popular Sadi Carnot (1837 – June 25, 1894), engineer and fourth President from 1887 of the Third French Republic (See Fig. 67).

HSG's relationship to the parish seems more than a religious one. He met Dr. George Joseph Bull (1848-1911) here, a Canadian ophthalmologist. He delivered numerous valuable scientific contributions chiefly on refraction, accommodation and strabismus [Wayenborgh, 2001] and published also on the stereoscope [Rohr, 1920].

The English architect and Father Osmund (Henry William) Cooke (1857-1901) [Argus, 2020] was Superior of the Passionists and will win HSG over to the Fourth International Scientific Catholic Congress at Fribourg, Switzerland in August 1897 [Tablet, 1897]. On November 2, 1895, the international Catholic weekly review wrote on occasion of 25th anniversary and the re-opening after decoration of the church:

"The present popular and energetic Superior is the Very Rev. Father Osmund Cooke, who for the last … years has been known to the congregation of St. Joseph's; to his lot it has fallen to keep the Silver Jubilee of the church, and to better hands it could not be confided" [Tablet, 1895].

Rev. Cooke had already prepared the plans of the Roman Catholic schools of St. Mungo in Glasgow, Scotland [News, 1890].



JOURNAL DES DÉBATS DU MERCREDI MATIN 4 JUILLET 1894

## Journal of Debates in Wednesday Morning 4 July 1894

The English and American colony celebrated yesterday, in the chapel of the Passionist Fathers, a solemn service of Requiem for the repose of Mr. Carnot's soul.

The church had been hung in black and a catafalque stood before the choir. The prayers were recited by Father Cuthbert, assisted by deacon Matthieu and Father Margaux, sub-deacon.

In the audience: Sir Edward and Lady Blount, Lady Lamb, Mrs. Candamo, Mrs. and Miss May, Mr. Louis Gould, Mr. Austin Taylor, the Countess of Coëtlogon, MM. Mac Adams, docteur Bull, M. Greenough, comtesse de Vaux, M. de Souza.

La colonie anglaise et américaine a fait célébrer hier, dans la chapelle des Pères passionnistes, un service solennel de *Requiem* pour le repos de l'âme de M. Carnot.

L'église avait été tendue de noir et devant le chœur se dressait un catafalque. Lesprières ont été récitées par le P. Cuthbert, assisté du diacre Matthieu et de l'abbé Margaux, sous-diacre.

Dans l'assistance : sir Edward et lady Blount, lady Lamb, Mme Candamo, Mrs et Miss May, M. Louis Gould, M. Austin Taylor, la comtesse de Coëtlogon, MM. Mac Adams, docteur Bull, M. Greenough, comtesse de Vaux, M. de Souza.

Figure 67 News Item by Journal of Debats [Debats, 1894] and Translation by the Authors.


Figure 68 Passionist Sign and 1868 Building of St. Joseph's Church (Phototypie A. Benoit, Neuilly-sur-Seine).

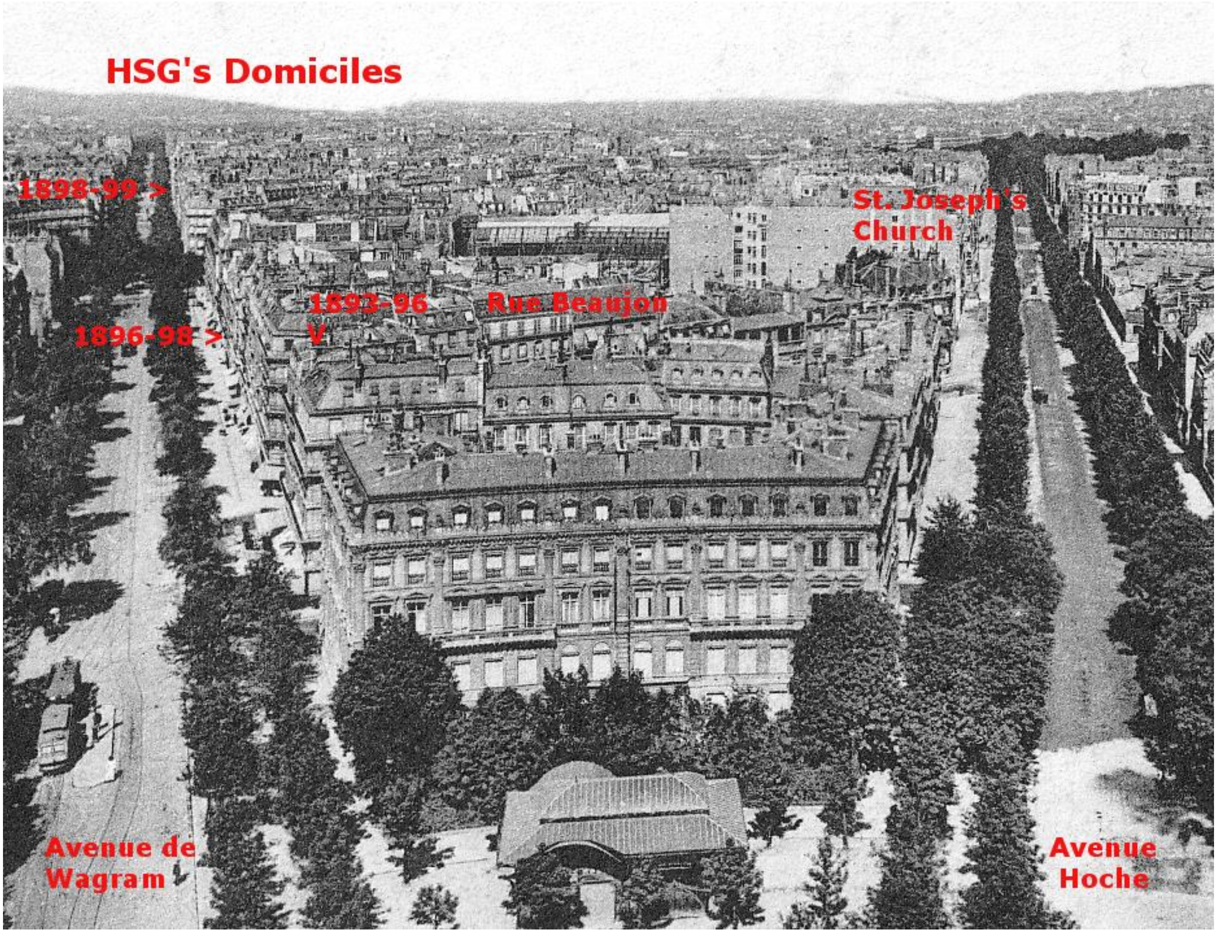



Figure 69 HSG's Quarter, Seen from Arc de Triomphe (219 Post Card of C. M. Editor) and Commented by the Authors.

The St. Joseph's Church dated from 1868 and was located at 50 Avenue Hoche, now there is a following church building from 1987. From his 21 Rue Beaujon domicile at the corner of Avenue de Wagram, HSG had to walk only 180 meters to the church, along his street and around the next corner to Avenue Hoche. In 1896 he moved three buildings away to 12 Avenue de Wagram and in 1898 again into this street. The distance to the church increases up to 400 meters. HSG wrote on March 06, 1898:

"I am giving up this apartement [sic] and as my movements are somewhat uncertain … Until further advice my address will be care of Mrs. Williams 38 Avenue Wagram" [BACZ 1579, 86].

HSG lived probably at furnished rooms with attendance because he and his Mother resided at the Bassano Hotel some years before (See Part 2/7). So he should depend always on the good intention of his landlady.

## 22. His Microscope Took Second Place behind Field Glasses

The simultaneous launching of two novel binocular instruments and some other ones stressed the microscope workshop and so both became competitors:

“Flawless fabrication required efficient foremen and engineers. In the beginning of large series production, Hebestreit and Zechner are particularly worth mentioning. Hebestreit was the foreman of the microscope mounting and worked very closely with Abbe. According to Hebestreit's private statements, one has to assume that he mounted the first field glasses and adjusted them” [Sonnefeld, 1955] (*in 1894*, the authors).

Ferdinand Hebestreit (1862-1928) jointed the factory in1876 as a trainee and became the second foreman from 1891and the first one from 1912 up to his retirement [Sonnefeld, 1926].

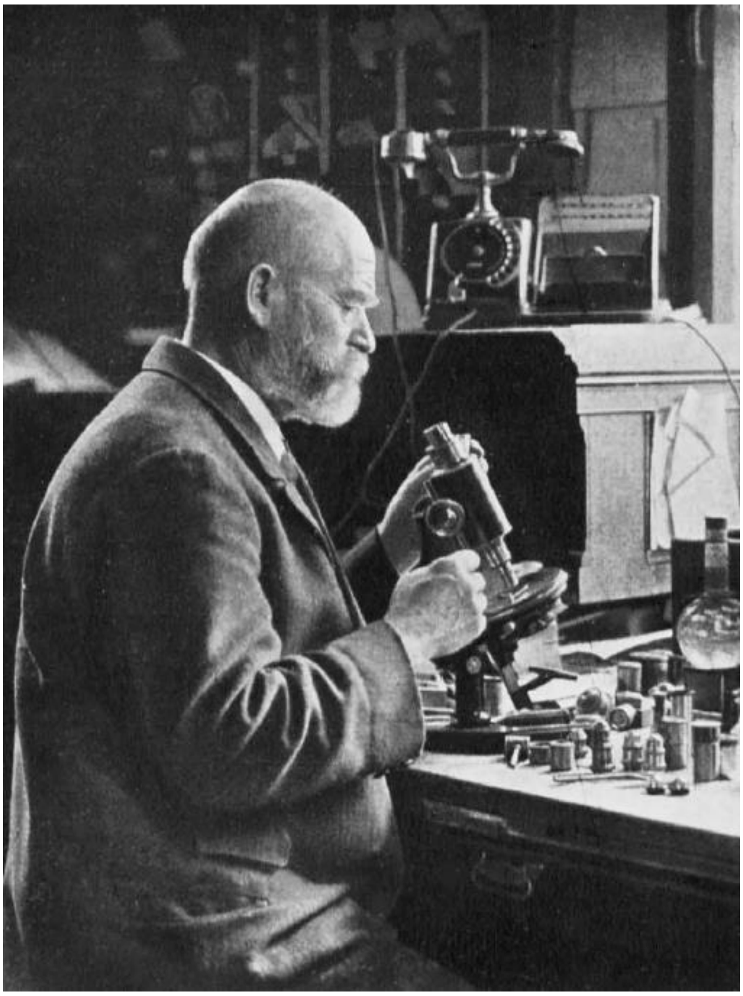


Figure 70 Ferdinand Hebestreit briefly before Retirement [Sonnefeld, 1926].

On June 12, 1894 Dr. Czapski wrote to Prof. Dohrn at Naples, Italy [Flitner, 2000]:

“So today I am still unable to fulfill my promise at the time and to send you a complete collection of the new instruments for viewing and selection (*See details in this part/19*, the authors), just as little as we could have sent anybody else ...

Not in spite of the validity of mine apologies to you and the other gentlemen there out of favor ... I will try to make you milder with a small down payment by sending the instrument that dedicates Carl Zeiss s. l. Johannes Müller *****. It is an 8-fold 'field glasses' – to hold on to this terminology for the time being ... the telescopes are still not properly baptized … this is really the first instrument that is given to a position or person who is not directly related to the workshop ... For the larger approval shipment promised to you, the whole assortment, I would now like to ask for a somewhat longer period, if possible until autumn. We have to send instruments to a great number of places, so that we should be short of them ... We cannot determine the prices for the time being, as there are still not enough manufactured to provide a secure basis. According to the data available so far, the instruments becomes dreadfully expensive ...”

On November 6, HSG announced returning of the orthomorphic microscope with its conical diaphragms and also the prism rotating apparatus for revision to Jena [BACZ 1578, 73]. No further information comes down on the requested or offered improvements. The authors guess that these revisions should be done which were promised by Dr. Czapski to Prof. Dohrn in June:” On the other hand, you will receive the improved models of all varieties in autumn …” [Flitner, 2000].

On November 24, HSG wrote [BACZ 1578, 74]:“I am very sorry to hear of illness during the past summer of your Prof. Dr. Abbe: prey give him my kind regard and also my best wishes for a speedy restoration to full health.” Nevertheless Abbe gave his first lecture on the new double telescopes to Jena’s Society of Natural Science and Medicine on July 29 [Krausse, 1993].

On November 19 of the following year HSG will add to his letter: ”P.S. the new field glass is much admired by all to whom I have shown it. Many thanks for prospectus of Hand Binocular telescopes” [BACZ 1578, 86-87].

On July 9, 1893 the Carl Zeiss Company had patented by DE 77086 a double telescope with enlarged objective distance which was issued on October 1, 1894.

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***** The s. l. abbreviation stands probably for Latin “sensu lato” meaning “in a wider sense”. Prof. Johannes (Peter) Mueller (1801-1858) was a German physiologist and anatomist and wrote “On the comparative physiology of the sense of sight of humans and animals, along with an attempt at movement of eyes and human gaze”. This 1826 book and Mueller’s scientific contributions caused Dr. Czapski to honor him.

Firma CARL ZEISS in JENA.

**Doppelfernrohr mit vergrößertem Objectivabstand.**

Figure 71 Early Field Glasses by Carl Zeiss Company (Courtesy Carl Zeiss Archive) and Headline of Patent Application.

The 1877 founded “Kaiserliches Patentamt” (German for Imperial Patent Office) at Berlin, Germany had declined the first Zeiss draft due to the 1854 patent application of the Italian Ignazio (Peter Paul) Porro (1801-1875): “The use of total or common reflection of light from surfaces, alone or in combination with refraction”. He was one of the Parisian opticians which have used already prisms for image erecting on Keplerian telescopes and for additional getting better image quality, a shorter tube length and a larger viewing field than provided by the simple Huygenian telescopes.

The before unknown priority of Porro was admitted and the Zeiss claim was modified: “Abbe deserves to have recognized that the double prism telescope is particularly suitable for increasing the objective distance compared to the eyepiece distance and thereby increasing the specific plastic, so that depth differences are better recognized” [König, 1937].

The first field glasses provided an objective distance of about twofold of eyepiece, the later developed relief telescopes reached more than the fivefold [Rohr, 1920].

On April 18, 1895 Dr. Czapski wrote to Prof. Mayer at Naples about preparing the serial production of the stereomicroscope [Flitner, 2000]:

"Your suggestion to make the binocular m (*microscope*, the authors) broken (to allow more comfortable head posture) ... is realizable, but expensive with the adjustment to the eye distances ... Since we have been extremely busy in microscopy since the winter, we have to put the binocular microscope aside for the time being."

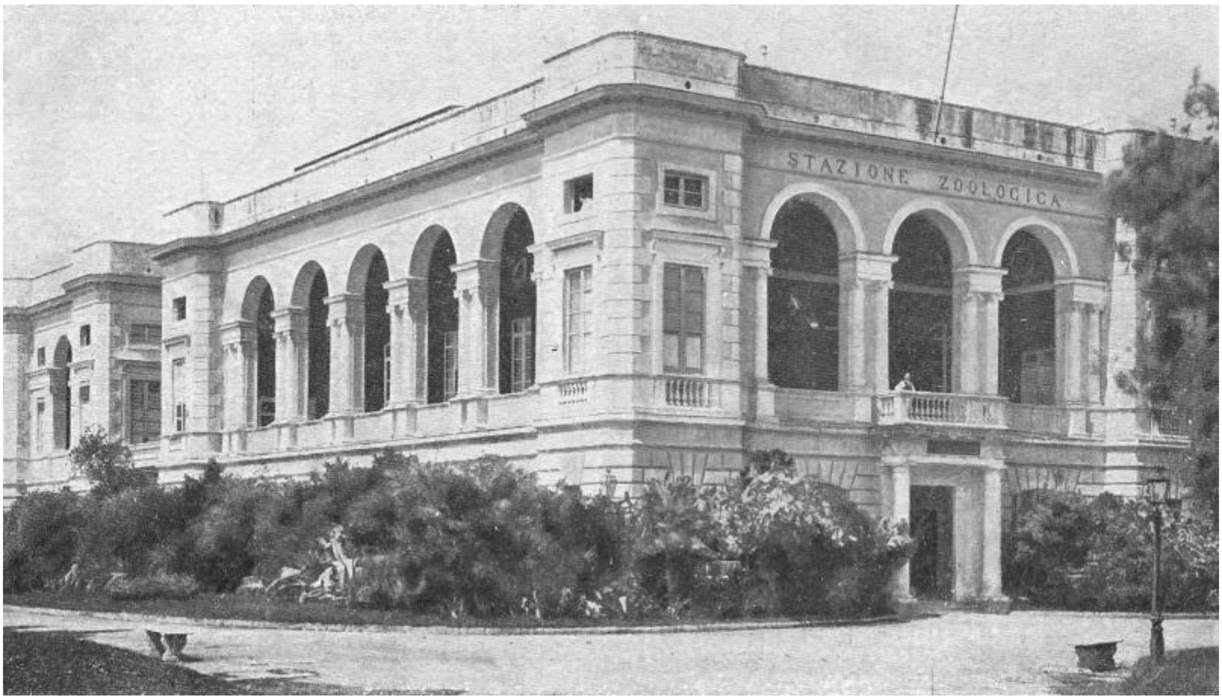


Figure 72 "Stazione Zoologica" and Aquarium at Naples about 1900 (90. Postcard by Lit De Luca&C Napoli).

The 1895 "Microscopes and Microscopic Accessories" Zeiss Catalogue presents an application of Porro's prisms earlier than the stereomicroscope. Page 91 offers the " * Erecting Eye-piece with Porro's Prisms" as the 57th item with a price of 40 Marks.

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*An asterisk * denotes that the instrument or device so marked has originated in our Works, having either been invented or first devised by us for the purpose named or at all events first made by us in the form here described.*

Figure 73 Legend of Asterisk from the Zeiss Catalogue [Zeiss, 1902].

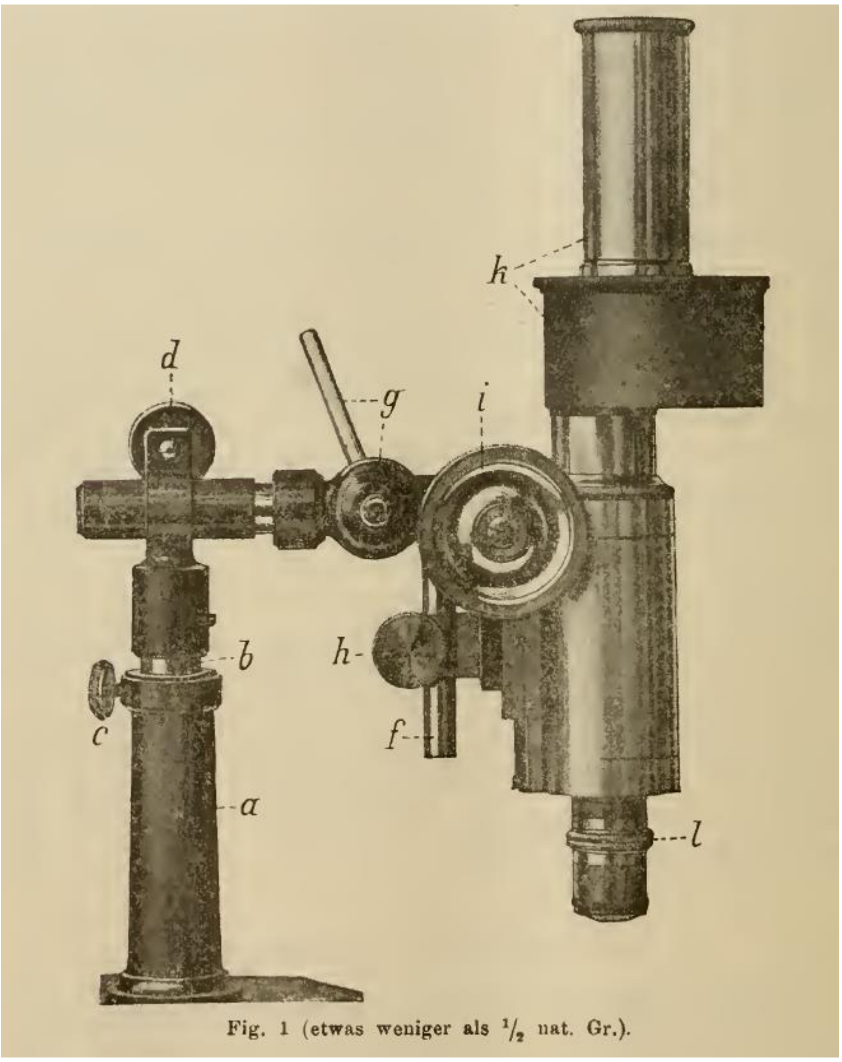



Figure 74 Zeiss Dissecting Microscope with Erecting Eyepiece Using Porro's Prism [Braus, 1895].

"This is inserted in the tube like an ordinary eye-piece. It contains encased in a drum the PORRO prisms, below these is the sleeve fitting the tube of the microscope and above is another sleeve which takes any eye-piece and whose axis is parallel but laterally displaced with respect to that of the tube" [Zeiss, 1895].

The chance of using any eyepiece is an advantage compared to the previous "AMICI Erecting Prism" (Italian optician, Giovanni Battista Amici, 1786-1863) which fits only the weakest No. 2 eyepiece. But the advantage of the last one could be the 30° tilted direction of vision related to the vertical tube axis resulting in a more convenient head posture.

## 23. His Predecessor in Protection by Patent

Why is there no patent application on HSG's stereomicroscope? The authors see two indications: At first Prof. Abbe's opinion on the protection by patent and at second Westien's patent application.

The 1896 Statute of Carl Zeiss Foundation states in Chapter III "General standards for the business activities of the foundation" according to section 44 [Statut, 1987]:

"With regard to such new products resulting from the sphere of activity of the foundations, improvements and the like which serve their purpose for essential purposes of study and scientific research, a restriction of the competition of others by patent or similar measures may not be brought about also in the future."

This generous rule of Prof. Abbe counted for quite a bit with the stereomicroscope, than the field glasses, as a mainly consumer product. So the first one was copied lawfully by some competitors, and the Carl Zeiss Company had to struggle against illegal plagiarisms of the second one for many years.

The patent application arose in partnership with a scientist and a mechanic. In 1886 beginning the German zoologist Prof. Franz Eilhard Schulze (1840-1921) asked Heinrich (Wilhelm Christoph) Westien (1856-1919) to construct a binocular dissecting loupe and to patent it. This court and university mechanic lived at Rostock, Germany [Kustodie, 2020] and Schulze did so also up to 1873 but in that time he was with the university at Berlin.

Prof. Schulze surely knew the optical contributions of the physiologist Prof. Ernst Wilhelm von Bruecke (1819-1892) who had graduated in medicine and was then a research assistant under Prof. Johannes (Peter) Mueller (1801-1858). Mueller was mentioned already in Czapski's letter in the foregoing paragraph. Bruecke invented a binocular dissecting spectacle in 1859. Two of its conditions can be found also on Westien's loupe:

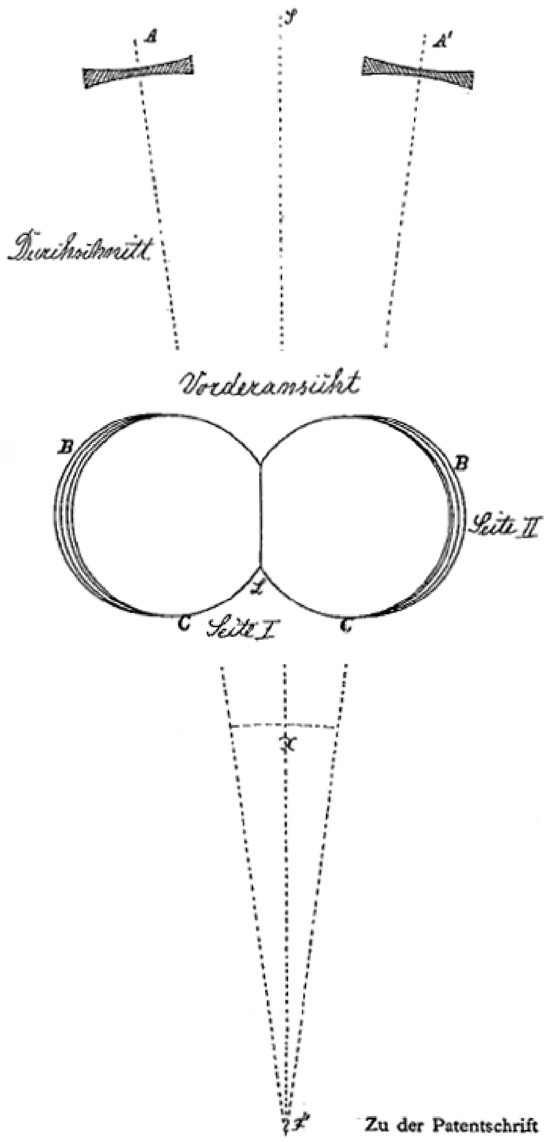
- The 6X or 10X loupes are from the kind of Chevalier-Bruecke consisting of a convex objective lens and a concave eye lens to get a longer working distance. The Parisian instrument maker Charles Chevalier (1804-1859) used such loupe already before.
- Both objective lenses are cut off at their contact line to ensure the straight vision lines between the sample and the eyes.

In May 25, 1886 patent application No. 38207 will describe nearly the concept of HSG's microscope:

HEINRICH WESTIEN in ROSTOCK (Mecklenburg).

**Doppel-Objectivlinsen mit gemeinschaftlichem Sehfelde.**

***Double objective lenses with a common field of view.***




**"Two concave eyepieces, as the drawing shows,
as a dissecting magnifier or
combined with two astronomical or terrestrial eyepieces,
as a microscope"**

***Sectional View >>>***

***Front View***

**Δ**

**"In cases where the x angle changes
which the two eye axes (light direction lines of the eyes)
form with one another,
e.g. with different eyes and visual distances,
the binocular objective lens systems get
a hinge movement at L"**

Zu der Patentschrift

**№ 38207.**

Figure 75 Double Lens Magnifier from Patent Specification and Westin's Comments Translated by the Authors.

Westien's Claim of DE 38207:

"Double objective lenses for close objects, consisting of two lenses or Objective lens systems, which are set against one another by grinding the edge so that the optical axes of the lenses coincide with the eye axes (light direction lines of the eyes), thus offering each eye a special visual field, and the content of both visual fields merged into one visual impression."

The description of invention goes beyond the claim:

“These side-by-side objective lenses can consist of two simple lenses or of two composite lens systems … The same can be combined with two concave eyepieces, as the drawing shows (*See Fig. 75*, the authors), as a dissecting magnifier or combined with two astronomical or terrestrial eyepieces, as a microscope, due to their light intensity, their depth of view and their stereoscopy.”

The figures of the patent application show two long distance loupes. Their concave lenses as eyepieces provide an image pair which is erected and true stereoscopic. Surely Westien had not carried out his microscopic proposals because he would notice that the astronomical or Keplerian eyepieces deliver a reversed and pseudoscopic image pair. In contrast the terrestrial eyepieces include the image erection by additional lenses (or prisms) and give a stereoscopic image pair. This version is equivalent to HSG’s demand on second objectives – these and Keplerian eyepieces together deliver the same function like terrestrial ones. Westien’s assertion is fulfilled with the loupes after Chevalier-Brücke or terrestrial eyepieces:

“In my binocular lens systems, in which no prisms are used, a real body is seen enlarged in its physical dimensions and appears because of binocular vision as a body with three dimensions ... [*namely*, the authors] two aerial images are formed by two lenses, which by two eyepieces are considered. A body is really seen binocularly” [*stereoscopically is meant*, the authors].

The L hinge between both objective lenses and also both tubes is not mentioned in the claim and not showed plainly in the figures. This hinge should meet different eye distances but would influence negatively the stereo imaging. A helpful angle variation needs a considerable mechanical expense and was not carried out. The axial shifting of the eyepieces was used to change their distance with effect from about the half of the eyepiece shift. Simultaneously tube length and magnification were varied and the focus setting was needed to correct.

The dissecting loupe was carried by a boom stand to get both hands free for dissecting work. The stand height and the focus setting is varied by a drive wheel and the boom length is adjustable by a clamping screw. The heavy iron base accepted various specimen support materials like glass, porcelain, wood or cork. Two concave mirrors for incident illumination were carried by rods equipped with ball-and-socket joints [Schulze, 1887]. There is no picture of this first device but its components could be similar to the cornea loupe [Zehender, 1887] which Westien designed also. Please see also Figure 44 in Part 3 for the Ernst Leitz device as a simplified Westien’s binocular dissecting loupe.

## 24. His Trouble for Preparing a Paper

In November 27, 1894 HSG wrote to Zeiss [BACZ 1578, 78-79]:

"In reply to your kind favour of Nov 20th I would in the first place thank you for the compliment you pay me in requesting me to write a scientific paper on orthomorphic microscope. An adequate technical treatment is beyond my capacity … I have made on black board in colored chalks a diagrammatic of the Orthomorphic Microscope which may render easier the understanding of my written demonstration. I hope shortly to have it properly copied by an expert draftsman in which case I will forward it to you…"

His three page manuscript dates from the same day [BACZ 1578, 75-77]:

"Orthomorphic Microscope

The Orthomorphic Microscope constructed by Messrs Carl Zeiss depends upon the equation:

(1) **A/a=D**

Where **A** is the distance between the centres [sic] of perspective of the eyes of the observer, **a** the distance between the centres of the object glasses and a coeficient [sic] of dilatation equal to the ratio of any line of the virtual object seen by the observer to the corresponding line of the object under the microscope.

This equation is easily demonstrated by means of a pair of imaginaries: Suppose twin brothers perfectly identical, say no. 1 James, no. 2 Charles, let each one be in a room by himself & let the rooms & all they contain be also identical. Give now to room no. 2 i.e. Charles' room & to all it contains including Charles a dilatation **D**. Then both James and Charles will see all objects just as they did before - moreover this will not be the case if room no. 2 & all its contents be subjected to any strain that is not a pure dilatation. Let **a** be the distance of realies [sic] of the perspective of the eyes of the either twin before the dilatation, **A** the corresponding distance for Charles after the dilatation. We have then

(2) **A=a D**

or

(1) **A/a=D**

If now we substitute for Charles a real observer, for the object seen by James a real object (*and*, the authors) for James eyes a pair of real object glasses so constructed that their optic centres & the centres of perspective of the real images they give coincide & then so place these object glasses that their optic centres satisfy equation no. 1 & if further with a second pair of suitably constructed object glasses & eyepieces the images formed by the 1st pair be magnified by the requisite amount (*than*, the authors) the images formed on the retinas will be the same as would have been formed by a real object of the same shape as that under observation but **D** times bigger:

The real and virtual solid objects coinciding at one point of their surfaces where the optic axes meet and the radii vectores [sic] from their centres of gravity to homologous points being parallel.

The magnification given by the 1st pair of object glasses is of course quite arbitrary. It is only necessary that it be such as to produce with suitable stopping a flat image of the 3 dimensional solid object under observation & with sufficient definition to admit of the needful magnification by the second pair object glasses. The efficiency of this instrument will depend upon the extent to which practical effect can be given to equation no. (1).

Paris November 27th 1894 Horatio M. S. Greenough"

HSG's paper starts clearly by the train of thought on the twins in illustration of his formula, but becomes vague in the optical conditions. He insists on both objective pairs nevertheless knowing the image erection by Porro-Abbe-prisms. He repeats his strange demand concerning the stereoscopic imaging: "… to produce with suitable stopping a flat image of the 3 dimensional solid object …"

On July 16, 1895 HSG offered sea urchin drawings for publishing. His investigation at Concarneau had ended in 1893 summer. During the following two months, HSG went and saw his Sister and Brother-in-Law at Dinan in Brittany.

A full year after sending his first manuscript, HSG and his confessor turned up at Jena without any prior announcement. A course could be a lecture by Prof. Ernst Haeckel (1834-1919) in December 13, 1895, "On the Phylogenesis of Echinoder-mata" [Krausse, 1993]. HSG was involved in this field by his investigations in sea urchins and Father Osmund Cooke could want to experience the famous evolutionist and freethought. In contrary to this fiction, we get an eyewitness report on HSG's lecture on the orthomorphic microscope which is given by Dr. (Louis Otto) Moritz von Rohr (1868-1940) who had started his probationary year with the Carl Zeiss Company in 1895 October [Tobies, 2017].

Dr. Moritz von Rohr wrote in his memoirs on the scientific evening held at the "Weimarischer Hof" restaurant [Rohr, 1928] which was run by an academically educated and Latin knowing proprietor.


Figure 76 Palm Garden of the Weimarischer Hof Restaurant and its Proprietor (Post Card by H. Leistenschneider Halle a. S.) and his Memorial Bust.

“But the most impressive visitor at those scientific evenings was an American microscopist HORATIO S. GREENOUGH, who appeared in Jena with his confessor in late autumn 95 and probably stayed a week. He made the orthomorphic microscope with us, which was supposed to provide a space-like image of small things observed in a double microscope. He gave us an English lecture - M. Fischer translated it sentence by sentence - in which he tried to imprint the meaning of his innovation on us with extremely simple means. Later (after 1904), when I had acquired some knowledge of history in this field, it was very strange to me that neither GREENOUGH himself nor one of the older listeners knew that D. BREWSTER in the fifties (*See Note*, the authors) had followed these geometrical ideas in a similarly simple way, by the way without coming to a really useful solution. In our workshop, GREENOUGH's suggestion led to the widespread double microscope that bears his name, but which, to his sorrow, did not depict true to space. I will have to deal with later, similar efforts by CZAPSKI and GEBHARDT …; but here may be the remark that GREENOUGH, who was quite amiable as a partner, had practically drilled himself into creating a true-to-space image in a properly built double microscope. My friend KÖHLER, with whom I later worked on this matter, finally broke off the almost endless correspondence with GREENOUGH. To his liking, we had built a device for low magnifications that was true to the space in the strict sense of the word, but he still found things that we couldn't possibly deal with anymore. As far as I know, he died in mental derangement. However, his letters gave us the impression of an unfortunate patient just a few years after his visit.”

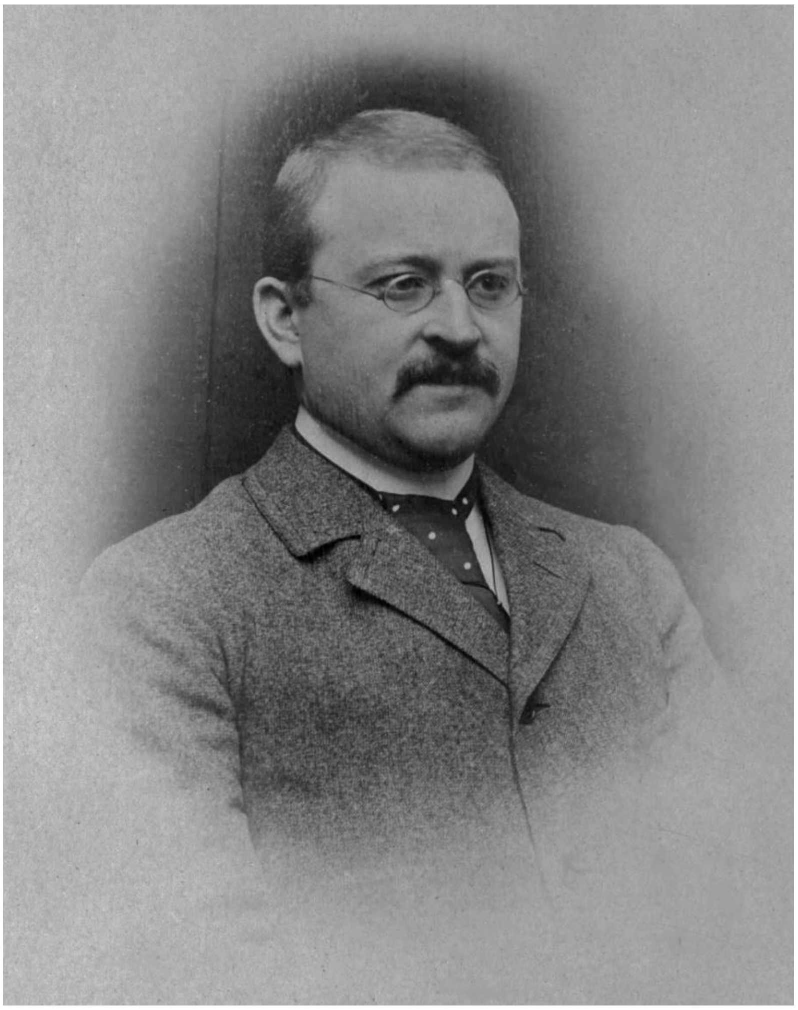


Figure 77 Dr. Moritz von Rohr in ca. 1900 (Courtesy Carl Zeiss Archive).

**Note:**

Sir David Brewster (1781-1868), a Scottish physicist, mathematic and astronomer dealt with the acquisition of stereoscopic photo pairs. In 1849 he gave the condition for correct stereo imaging of large specimen e.g. monuments (HSG's symbols are putted in by the authors): Both objectives need the **a** distance which has to be the **A** eye distance of the observer multiplied by the **E** reduction factor between specimen and photo [Rohr, 1920].

Brewster's formula **a=A E** can be transformed to HSG's one **A/a=D** by **E=1/D** due to the inverse meaning of the **D** magnification and the **E** reduction. HSG didn't know the rule of his predecessor and to his credit it must be said that he found and applied firstly this rule to the double-tube microscope.

On December 30 HSG noted that he returned to Paris few days ago and had begun to write a new paper on the Orthomorphic Microscope. He asked for “a diagram of meridian section of the human eye with the position of the centre [sic] of projection marked thereon” [BACZ 1578, 88] which he got by Zeiss reply of January 7, 1896 [BACZ 1578, 93].

On January 24, HSG announced the shipment of four boxes of capillary tubes and a descriptive note book. We see that he considered his specimen profitable for the factory. Further he mentioned firstly a health reduction [BACZ 1578, 94]:

“I will take this occasion to say that as I am feeling tired, my physician advises the setting aside of all serious work for the present and preparation of the paper I had begun for you is consequently delayed.”

Dr. Czapski replied [BACZ 1578, 1]: “From your favor of the 24th we learn with sincere regret that your health is not in a satisfactory state and that you therefore need some time for recreation. We hope that you will soon be restored.”

The tiredness caused surely that HSG and his Brother-in-law were mentioned on season book of Châtel-Guyon, Région d’Auvergne-Rhôe-Alpes in following summer, located on half way between Paris and Marseille: “The charming resort already has an aristocratic colony of bathers among whom we can cite: Prince and Princess Pio of Savoie, Mrs. the Countess of Alcantara … Mr. Hervoches du Quilliou … Mr. Horatio S. Greenough, etc., etc.” [Le Gaulois, 1896].


LE GAULOIS — SAMEDI 20 JUIN 1896

CARNET DE LA SAISON

Châtel-Guyon

La charmante station possède déjà une aristocratique colonie de baigneurs parmi lesquels nous pouvons citer : le prince et la princesse Pio de Savoie, Mme la comtesse d’Alcantara, Mme Cadet de Vaux, Mme Pierre-Bey, Mme la comtesse de Chabannes, M. Robert de Chabannes, M. Hervoches du Quilliou, Mme la comtesse et MM. Henry et Gontran de La Baume, M. Horatio S. Greenough, etc., etc.

Baden-Baden

Figure 78 News Item of Saturday June 20, 1896 [Le Gaulois, 1896].


Figure 79 Parc and Theater at Châtel-Guyon about 1900 (128 ND Phot Post Card).

HSG added the basic microscope structure and both rotators to a type written abstract of October 7, 1896 which was sent not until December:

"Orthomorphic Microscope & Accessory Apparatus.

The Orthomorphic microscope constructed by Messrs Carl Zeiss of Jena in accordance with my indications depends upon the equation,

No. 1. **A/a=D**.

where **A** is the distance between the centres [sic] of projection of the eyes of the observer; **a**, the corresponding distance between the centres of projection of a pair of object glasses; and **D** an arbitrary parameter, (*In February 1897 HSG will replace the following*, the authors) expressing the ratio of any homologous dimension of the virtual solid object seen by the observer to that of the "similar" real object under the microscope.

I shall not in this paper give the demonstration of equation No. 1. because in order to do so it would be necessary for me to explain and set forth a private method of study.

Now this method has for one of its essentials the use of three dimensional pictographs and to execute these pictographs in such manner as to be generally understood and also suitable for publication would involve such very great expense, that in my opinion this reason is of itself sufficient for withholding the demonstration of aquation [sic] 1. I have prepared a somewhat full statement of the scientific considerations leading up to equation 1. together with a twofold demonstration of this equation and shall be pleased to explain the same privately to any one desiring further information concerning the scientific aspects of orthomorphic vision than can be given in this paper (*End of the1897 February revision*, the authors).

Here I shall content myself with a brief statement of what orthomorphic vision is and of its advantages, and a short description of the orthomorphic microscope itself.

Orthomorphic vision is that special case of stereoscopic vision which corresponds to the determination of a solid detached object by two of its central projections: so that the ratio of ”field” to “depth” is seen at its true value. This kind of vision only obtains within the near neighbourhood [sic] of the observer and does not extend at the utmost beyond a few meters.

When a solid object can be seen orthomorphically and from any direction its real shape may be well-known. That this is so is well shewn [sic] by the fact that a skilful sculpter [sic] endowed with good visual memory can execute from memory a good model of an object that he has carefully studied and in so studying it he uses orthomorphic vision. Mere stereoscopic vision that is not orthomorphic will not yield the same result; still less will monocular vision or its equivalent. The exceeding inadequateness of monocular vision or its equivalents for the seeing of real three dimensional shape is I think, not at all fully realized even by the scientific public; and for this I will now state one reason. The monocular aspect of an object has at least a two-fold significance. It is both an image and a symbol. Now because of the results of acquired experience, its significance as a sign is the preponderating one, whenever we have to deal with the monocular aspect of a known object: so that the mind’s eye sees the solid object by means of the monocular image. When, however, we have to deal with the monocular aspect of a totally unknown object the case is entirely different. The real shape is of course not determined and the mind is entirely unable to judge as to what it may be. I remember some years ago, having vainly struggled for more than an hour, nearer two, I think, to understand certain facts in the embryology of “clepsina” (*kind of leeches*, the authors) from a published paper illustrated with numerous good drawings. Afterwards, in 1892, the author, Professor Dr. C. O. Whitman very kindly shewed me a set of solid models illustrating the same paper, and in a few minutes I easily understood the matter which before had completely baffled me.

The orthomorphic microscope is a twin microscope satisfying equation 1. and furnished with an electric light attachment: either this light or somewhat condensed sunlight being an essential of the orthomorphic microscope in order to admit of very heavy stopping at the centres of perspective of the object glasses, for the attainment of sufficient depth of focus. The instrument ~~is~~ / as (*corrected by hand*, the authors) / constructed, given a good approximation to the condition of naked eye orthomorphic vision and when furnished with prism-rotating apparatus attachment permits of a solid object's being seen from above and below and also from any lateral direction, so that its real shape can be well observed and known. In this last apparatus the rotation is about a vertical axis.

The capillary rotating apparatus admits of rotating a minute object under the microscope about a horizontal axis. I have used it for this study of sea-urchin eggs and embryos; it is designed more especially for use with immersion object glasses and may be used either with water or homogeneous immersion in which last case the preparation must be in oil of cedar of index 1.51. This instrument is a modification of one by the late Dr. Chabry, Assistant director of the laboratory of Marine Zoology at Concarneau, it gives good results, even with water and thus permits of the study of living eggs and embryos and larvae under very favourable [sic] conditions.

The technical description of the orthomorphic microscope as actually constructed together with the accessory prism-rotating and capillary rotating apparatus I leave to Prof. Dr. Abbe, Dr. Siegfried Czapski and the scientific staff of Messrs Carl Zeiss.

| Signed | Horatio S. Greenough
Paris, October 7 th. 1896"

HSG wrote "I preferred to send type written copies as being more easily legible" [BACZ 1578, 96]. He dreamed "that the ratio of field to depth is seen at its true value". In fact the optics allows this true ratio only by the helpless 1x magnification, please see page 31 of Part 3/15. He evaded the demonstration of his equation in this abstract. At the end of 1896, he tried to justify his formula by the following type written letter [BACZ 1579, 8-10]:

“12 Avenue Wagram / Paris (*See A Note*, the authors) / December 17th, 1896.

Messrs Carl Zeiss R21 (*written by hand,* the authors)

Gentleman,

Please excuse delay in answering esteemed favor of your Dr. Czapski of the 9th inst., I have this day returned from Brittany where I have been for some woodcock shooting (*See B Note*, the authors) at my brother-in-law’s, and found Dr. Czapski’s letter awaiting me.

In reply I have the pleasure to hand you herewith abstract of my paper, and moreover I would say that it is this abstract and not the full paper that I intend to read at Freiburg next May!

My reasons for this being that the production of my full paper in a form suitable both for public demonstration and for subsequent publication would be much too expensive for me to undertake, and also that time is lacking for the necessary work to be done.

I will however add, for your private information, that the demonstration of my equation **A/a=D** upon which the orthomorphic microscope depends, or is based, depends itself upon what I believe to be a new axiom in mathematical philosophy: which axiom may be stated as follows, viz.

‘In variance / Invariance should be in one word (*added by hand,* the authors) / of the proximate efficient cause is the necessary and also the sufficient condition to the operation of the principle of least action.’ (*See C Note*, the authors)

Hoping that the abstract I send may be found suitable by yourself for publication in your forthcoming catalogue

I remain, gentleman,

Very truly yours,

| Signed | Horatio S. Greenough.

P.S. “The proposition“ / in quotation marks (*added by hand,* the authors) / cannot be demonstrated because it is axiomatic. Illustrations of its operation are all that is possible. I will here give the simplest I have thought of, or at least one of the simplest, because it is easily stated in ordinary language and can be understood by any educated person, my sister Madame Hervoches du Quilliou, who has no mathematical training having comprehended it immediately and with ease.

Let it be required for a man in a level, that is flat, park or garden to walk to a distant tree in accordance with the principle of least action: here the proximate efficient cause is two-fold, viz. the length of each step and the direction of each step, hence the man must in order to go to the tree with the least action take steps of even length and of constant direction, i.e. he must walk in a straight line from his position to the tree.

The axiomatic proposition that in Euclidian space the shortest distance between two points is a straight line joining such points is thus exhibited as depending upon another axiom still more fundamental! The foregoing is written for your private information and I venture to hope I have made myself comprehensible although I know that this is difficult "on paper" and without the opportunity of asking an answering such questions as may occur to ~~demand~~ / the mind (*corrected by hand,* the authors) /; questions which naturally present themselves to the mind when dealing with a wholly new subject.

| Signed | Horatio S. Greenough

December 18th, 1896"

**A Note:**

We learn that HSG moved after February 17, 1896. The Avenue de Wagram (See also Fig. 69) is directed straightly to the Arc de Triomphe. The 1897 member list of Société Zoologique de France updates last but one 30 Rue de Bassano to 12 Avenue de Wagram, the cause seems HSG's renewed contact.

**B Note:**

The woodcock shooting remembered HSG that the Japanese Snipes or Latham's snipes (Gallinago hardwickii) were shipped to and sold at San Francisco. He asked his Société Zoologique colleagues on information about this snipe which is much larger than the European woodcock (Scolopax rusticola) [Bulletin, 1896].

SÉANCE DU 22 DÉCEMBRE 1896 213

M. H. S. GREENOUGH sera reconnaissant à celui de ses confrères qui voudra bien le renseigner au sujet d'un Scolopacide japonais, non décrit dans les traités d'ornithologie. Il s'agit d'une Bécasse qui serait bien plus grande que celle de France et serait de la taille d'une petite Poule ; le bec aurait à peu près la même longueur que chez l'espèce européenne et, par conséquent, serait relativement plus court. Cette espèce serait expédiée en Amérique par les paquebots et se vendrait chez les marchands de gibier de San-Francisco. Elle serait enfin représentée sur certaines céramiques japonaises.

Figure 80 Note by Bulletin de la Société Zoologique de France [Bulletin, 1896].

**C Note:**

The principle of least action states that in all natural phenomena a quantity called action tends to be minimized. The French mathematic Pierre (Louis Moreau de) Maupertuis (1698 –1759) said "Nature is thrifty in all its actions" and he is credited to discover the principle. Even before his compatriot Pierre de Fermat (1607–1665) had postulated the principle of least time or Fermat's Principle: "Light travels between two given points along the path of shortest time". Hamilton's principle or also called principle of stationary action generalizes both after 1835. HSG thought that he had to add his new axiom – should it justify his demand for straight vision lines between the sample and the eyes?

In beginning of February 1897 HSG asked for the publication date of the catalogue concerning the Orthomorphic Microscope [BACZ 1579, 22]. Two weeks later, HSG pulled back his doubtful axiom [BACZ 1579, 6] due to Dr. Czapski's reply:

"12 Avenue Wagram / Paris Feby. 24th 1897

Dear Dr. Czapski

Since acknowledgeing [sic] receipt of your post card of Feby.19th I have decided that it will be very much better to omit allusion to my own private method of mathematical study, your discovery of a simple demonstration of my equation based on generally adopted principles rendering such mention on my part quite needless & in fact decidely [sic] inexpedient.

I have just rewritten the paper I intend reading at Freiburg & will send you copy of same under registered cover as soon as I shall have had time to write it out. – When you receive it please substitute it for the previous paper dated Oct. 7th 1896 and make such use of it as you may see fit.

Very truly yours

Horatio S. Greenough"

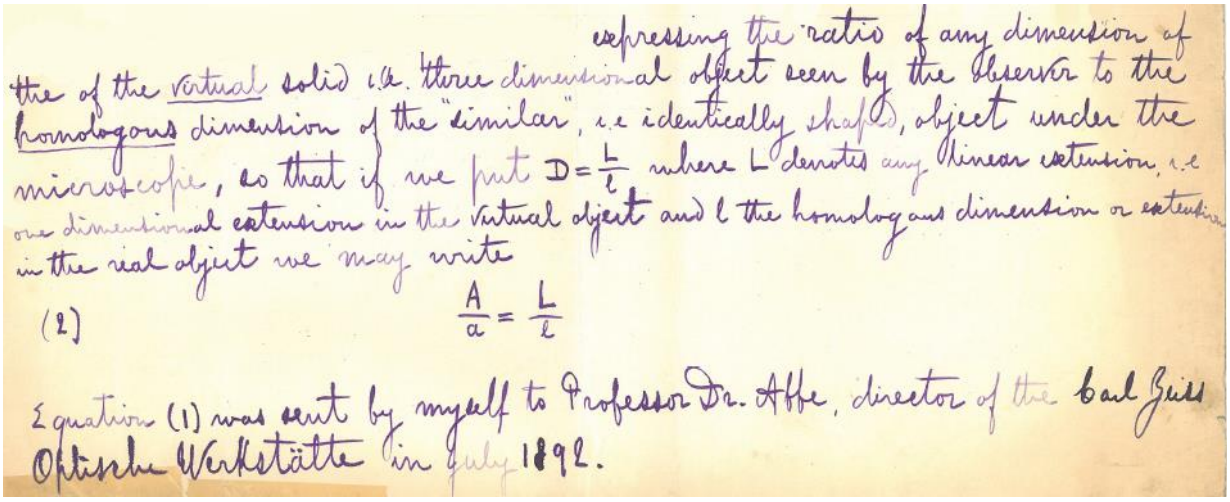
The authors guess that Dr. Czapski had pointed to his supervisor, Hermann (Ludwig, Ferdinand) von Helmholtz (1821-1894), because Czapski will mention him also in the 1897 paper. In 1857 Helmholtz had used Brewster's rule as the condition for the orthomorphic vision with a telescopic stereoscope.

An oversized and hand written paper [BACZ 1579, 3-4] dates from the same day but only the following passage differs from the HSG abstract of October 7, 1896 (Please see the marked passage on page 41-42):

"… expressing the ratio of any dimension of the of the [sic] virtual solid i.e. three dimensional object seen by the observer to the homologous dimension of the "similar", i.e. identically shaped, object under the microscope, so that if we put **D=L/l** when **L** denotes any linear extension, i.e. one dimensional extension in the virtual object and **l** the homologous dimension or extension in the real object we may write

(2) **A/a=L/l**

Equation (1) was sent by myself to Professor Dr. Abbe, director of the Carl Zeiss Optische Werkstätte in July 1892."



expressing the ratio of any dimension of
the of the virtual solid i.e. three dimensional object seen by the observer to the
homologous dimension of the "similar", i.e. identically shaped, object under the
microscope, so that if we put $D = \frac{L}{l}$ where L denotes any linear extension, i.e
one dimensional extension in the virtual object and l the homologous dimension or extension
in the real object we may write

(2) $\frac{A}{a} = \frac{L}{l}$

Equation (1) was sent by myself to Professor Dr. Abbe, director of the Carl Zeiss
Optische Werkstätte in July 1892.

Figure 81 Revised Passage of HSG's Paper of February 24, 1897 [BACZ 1579, 3].

HSG goes an essential step by "the virtual solid i.e. three dimensional object seen by the observer". So he says goodbye to the strange "flat image" like a photo in the stereoscope. The image space is a prerequisite for focusing by accommodation for getting more image depth. The second equation would stand for the demand on distortion-free imaging when the linear extension should lay in a plane perpendicular to the optical axis. A skew linear extension would be equivalent to his impossible demand: "the ratio of field to depth is seen at its true value".

HSG tried to create a paper but will not succeed to publish it by himself. Dr. Czapski and Dr. Gebhardt will cite his fundamental ideas on the orthomorphy and the three instruments in their 1897 paper. HSG will overemphasize his demand on the pure orthomorphy and come into conflict with the pragmatism of the Zeiss Company. Opinions of Parisian scientists shall support HSG's wishes. He will search hardly for a theoretical reason for his 'Kindergarten' formula e.g. by the projective geometry.

**References: We acknowledge Dr. M. B. for his intensive literature researches.**

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The authors welcome any suggestions for corrections or improvement.
They can be reached at:

R. Jordan Kreindler: transientbox@gmail.com

Berndt-Joachim Lau: stereomicro@gmx.de

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