Reversible prints providing the sensation of depth
by M. G. Lippmann ([1])

1. The current most perfect photographic print only shows one aspect of reality; it reduces to a single image fixed on a plane, similar to a drawing or a hand-drawn painting. The direct view of reality offers, as we know, infinitely more variety. We see objects in space, in their true size, and with depth, not in a plane. Furthermore, their aspect changes with the location of the observer; the different layers of the view move with respect to one another; the perspective gets modified, the hidden parts do not stay the same; and finally, if the beholder looks at the exterior world through a window, he has the freedom to see the various parts of a landscape successively framed by the opening, and as a result, different objects appear to him successively.

Can we request that Photography renders the full variety offered by the direct observation of objects? Is it possible to create a photographic print in such a manner that it represents the exterior world framed, in appearance, between the boundaries of the print, as if those boundaries were that of a window opened on reality? It appears that yes, we can request from Photography infinitely more than from the human hand. Here I will attempt to provide a solution to this problem.

2. The sensitive plaque is for this purpose made as follows: A layer of emulsion is applied on the posterior face of a transparent sheet; the anterior face, instead of being blank, similarly to currently used films, is covered with small bumps with a spherical shape. Each bump is meant to function as a converging lens to project an image of the objects onto an element of the sensitive emulsion layer. Thereby, the sensitive plaque is divided into a large number of tiny darkrooms that are side by side and which I name cells.

This layout is reminiscent of the insect eye made of the crystalline lenses (of the dytiscidae, for instance), the exterior surface of the eye made of a large number of transparent corneas, laid out hexagonally, as the cells of a beehive. The mini retinas of the compound eye are just replaced here by the layer of sensitive emulsion ([2]).

3. The first property of such a system is to provide photographic images without introducing it in a darkroom. It suffices to expose it in plain light in front of the objects to be represented. The use of a darkroom not needed, because each cell is a darkroom in itself. It is of course necessary to store the strip in a lightproof box, open it only for the time required for exposure, and keep it still during that time, then close the box, and finally process and fix it in darkness.

The result of these operations is a series of small microscopic images, each fixed on the retina of one of the cells.

If one could look at the photographic print from behind, that is, from the same side as the emulsion, one would see only a system of small side-by-side images, in equal number as the cells.

The observer should be on the anterior side, his eyes being at an arbitrary distance from the plaque, and the plaque should be lit by transparency with diffuse light: for instance being against a piece of diffuse glass. In this case, he sees a unique image, located in space and in its original size.

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1 **Communication at the French Society of Physics: Session of March 20th, 1908.**

2 Let us recall that the compound eye of an insect provides a series of tiny images which can be photographed. These images have been photographed by Dr. Vigier, who used coleoptera eyes (1905-1907)

Actually, during the exposure, the rays originating from a frontal point A converge at the back of some cell at a point *a* image of A (Fig. 1). This image is developed and fixed by the photographic operations. When later we lit *a*, the rays leaving *a* will converge in A, according to the principle of the inverse return of the rays. This applies to all the cells that have received rays emitted by A: all carry some images *a*, *a*, *a*, that have the point A as a conjugate image; all emit light pencils that converge in A. The set of these narrow pencils form therefore a wide pencil that converges on A (see Fig, 1): it is a wide pencil, since it has the entire sensitive plaque as its basis, or at least the part of it from where the point A was visible ([3]).

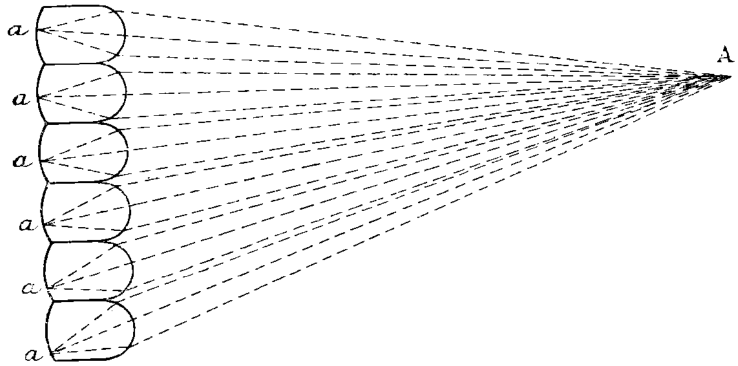

Fig. 1.

Thus, thanks to the reversibility property of the darkroom, which in turn is inherited by the system of linked darkrooms, it is sufficient to lit this system from behind to project in space a real image that occupies the location of the captured point A. The same applies to the other points B, C, D of the photographed subject. All these points are reconstructed as real images.

4. The traditional development processes results in a negative. The eye thus sees a negative; furthermore, there is a flip from right to left and from top to bottom; it is thus necessary to apply a double rectification, photographic and geometric.

It is possible to get this double rectification by copying the negative print N on a virgin plaque P, built the same way as N. To perform this copy, one puts the two plaques in front of each other, the frontal faces, having the small lenses, facing each other, at an arbitrary distance. Contact is not needed, neither is the parallelism of the two plaques. The cells can have different sizes on the two plaques.

After developing and printing, the plaque P gives a rectified positive virtual image equal to the object; in other words, this image is coincident with the photographed object.

To prove it, let us consider again a material point A part of the object to be reproduced. We first photographed it on the plaque N; let's assume that this one did not move during the photographic operations. If we then lit from behind, the emerging rays form, in the air, a wide pencil that converges to A. Let's now interpose the plaque P on the path of these converging rays. Any cell of P makes the rays that it receives converge to a point *a'* located on the sensitive layer; *a'* is the image of the point A, which constitutes in this case a virtual object; *a'* is photographically fixed; when we later lit it, *a'* generates rays that follow the same path as the incoming rays, but in reverse direction, that is, the emerging rays diverge from A. The system of all the points as *a'* thus generate a wide pencil diverging from A; in other words, this point gives a virtual image of A coinciding with A.

3 In the case of a landscape, of a 3D subject, there may be hidden parts which change according to the view point.

The same holds for all the points B, C, D of the object to be photographed. The eye thus sees a virtual image coinciding with the object.

The aspect of this image is the same as that of the object. Similarly to the case of a virtual image given by a planar mirror, one believes that he sees again the object in its original size beyond the apparatus; the image moves and changes aspect when the plaque moves; finally the aspect is different for both eyes, and the binocular stereoscopic relief is produced with the help of the stereo vision, similarly to the case of a planar mirror.

Finally, the image given by P is virtual and equal to the object, the eye focuses as it would for the object, and its distance to the plaque can be arbitrary.

5. While the theory of reversible plaque is very simple, its building faces serious technical difficulties. Until now I was able to realize it only in a very imperfect way, enough however to check the principle of the system, the existence of the real image resulting from the small cell images, and its uniqueness.

Some trials to use as the transparent slide a collodion slide, molded by heat, led to bad results. Collodion and celluloid have very bad optical properties. M de Chardonnet was kind enough to advise me to avoid their use, and instead to build each cell with an appropriately shaped glass shaft; I was right to follow his point of view.

One can find in shops small “Stanhopes” magnifying glasses, shaped as sticks of 6 mm long and square section of 2.5 mm. One of the ends is shaped as spherical surface; the other end is planar and at the focal point of the first. These sticks have been put one near the other in such a way that their flat ends are in the same plane; care was taken to darken the lateral surfaces with Japan Black lacquer; finally, the surfaces were covered with a gelatin-bromide emulsion without grain.

Plaques constituted in this way have been exposed in front of various objects (window, lamp). I could see after developing and fixing the unique image resulting in real size. This image is in the space since it does not move when the plaque is moved in a parallel way to itself; on the contrary it follows the eye movements when the plaque does not move: those are verifications of the theory.

The continuity of the unique image does not depend on the cells size: it is verified if the cells are in contact through surfaces of negligible opposition. Provided the pigment layer is very thin, there is no drawback in increasing the size of the cells, except that the plaque would get thicker and more massive; however, it seems to be easier to build properly elements which are not too small.