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PHOTOGRAPHY. – Reversible Prints. Integral Photographs.
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1. The current most perfect photographic print only shows one aspect of reality; it reduces to a single image fixed in 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. Consider a film similar to the ones currently used, formed by a thin transparent strip of celluloid or collodion covered on one of its faces by a light-sensitive emulsion. Assume that, before laying the emulsion on the strip, the latter was hot-pressed with some kind of waffling-machine so as to create on each of its faces a large number of small protrusions with the shape of a spherical segment. Each of these protrusions covering the anterior face of the strip, the face that will remain uncovered, will act as a converging lens. Each of the protrusions of the posterior face is covered with sensitive emulsion et is meant to receive the image formed by the small lenses of the anterior face.

Fig. 1.

Figure 1 shows a magnified section of such a film. In order for the image to be focused, the corresponding segments must have the same center of curvature and the ratio between the front and back radii must be n-1, where n is the index of refraction of celluloid for the most photographically-active rays. The system formed by any of the small front lenses and by the corresponding portion of sensitive layer constitutes a small spherical dark room similar to the eye : the lens corresponds to the transparent cornea and the sensitive layer replaces the retina. There is no crystalline lens [the lens of the eye]; this organ is not necessary here because, given its small diameter, the minuscule dark room cannot remain focused on any moderately far object [Not sure I fully understand this sentence]. It is useful that a layer of black pigment optically insulates each element from its neighbors. If, for short, we call each elementary dark room a *cell*, we see that the entire strip is a fabric of such juxtaposed cells. If each cell is a simple eye, their combination is reminiscent of the compound eye of insects.

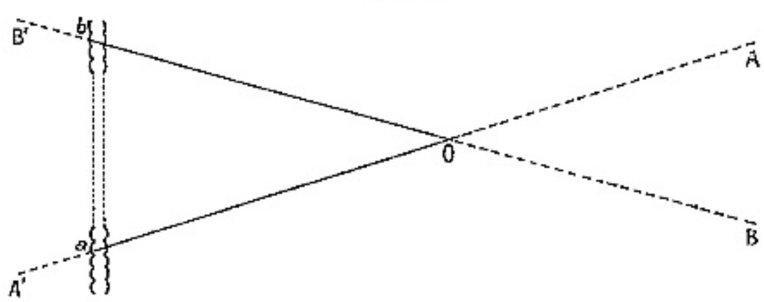
3. The first property of such a system is to provide photographic images without introducing it in a dark room. It suffices to expose it in plain light in front of the objects to be represented. The usage of a dark room is not useful because each cell of the film is itself a dark room. It is of course 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.

Seen from the sensitive-layer side, these images could not be distinguished with the naked eye and would look like a uniform grey layer. However, assume that the eye is on the other side and the print is backlit using diffuse light, such as that provided by a white piece of paper placed against the strip. The eye would then see, instead of a system of small images, *a single resulting image projected into space in true size*.

Indeed, consider (fig 2) an arbitrary point *a* on one of the small photographic images. The rays leave the cell parallel to one another since *a* is by construction at the focus of the refractive lens. The eye placed at O perceives them as if *a* was sent back to infinity in direction O*a*.

Fig. 2.



In addition, the direction of the emerging bundle with origin at point *a* is precisely that of the incident bundle which, during the exposure, was focused into *a*. This incident bundle originated from a point A of the landscape. The eye thus perceives the photographic image of point A as if projected in space in the direction of the line going from the optical center of the eye to point A, or more exactly in the prolongation of this direction. The same applies to a second point B of the landscape and its photographic image *b*: the latter is send to infinity according to the extension of line OB. The directions are preserved, as well as the angles and apparent lengths.

This demonstration can be given a slightly different form. We know that a dark room where the snapshot it has taken is put back is a reversible apparatus. [We know that if we take a snapshot with a given darkroom and put it back inside the dark room, we obtain a reversible apparatus]. That is, if we illuminate a point *a* of the snapshot that is the sharp image of an exterior point A, the rays converge to A. This proposition applies to all points *a, b, c, …,* sharp images of points A, B, C, … It follows that all the real images thus created occupy in space, relative to the system of dark rooms, and relative to one another, the same position as the actual points initially used as models. Their system thus constitutes a three-dimensional virtual object that is optically equivalent, for the eye of a beholder, to the system of actual points that we seek to reproduce. The eye will perceive, under the condition that it accommodates, with the aspect that corresponds to its location.

This aspect changes with the eye position. Since, furthermore, the two eyes occupy different positions, they see the corresponding perspectives: the conditions of depth perception with binocular vision are met without using a steroscope. In summary, the film created as described above allows one to take pictures without a dark room and then shows the photographed objects with their true size and depth, without any stereoscopic apparatus. Furthermore, their aspect changes with the position of the beholder, as if he was in the presence of reality.

4. If we simply observe the film processed as a negative after the exposure, the image is a negative; bright points appear black. Furthermore, the image is geometrically inverted, upside down, and left-to-right: Because each point *a* is seen along line OA. It is therefore necessary to perform a rectification.

This rectification can be obtained in two ways. First, one ca perform the photographic operations in such a way as to obtain a positive rather than a negative; one performs the geometric rectification by rotating the film in the plane by 180 degrees.

A better method would consist in copying the processed negative print onto a second film placed in front of the first one at an arbitrary distance of a few centimeters. Contact is not necessary as it would be for a copy with a press, because each cell of the second film sees, in a way, the inverted negative image and rectifies it with a second inversion. The advantage of this second method is to multiply the number of positive copies as much as one wants.

5. Each image perceived in space by the beholder's eye is therefore the resultant, due to the summation of elements borrowed from each of the little images imprinted at the back of the *cells*. The perceived image is continuous if the cells are sufficiently close. Indeed, if the aperture of the pupil were infinitely close, each of the elements would be a point and would reduce to separate points onto the retina of the observer; they would however appear adjacent, under the condition that the cells be small enough and close enough so that they cannot be distinguished. But the aperture of the pupil is finite , each element therefore has a finite extent, and they connect in reality, under the only condition that the linear distance between two cells be less than the pupil's aperture.

At each moment, the observed image is limited by the boundaries of the print, like the view of exterior objects would be limited by the frames of a window that one looks through. By moving one's head, other objects can be seen, framed by the same boundary, and with a sufficient motion, one can survey a landscape. It could appear unbelievable, a priori, that a single photographic print could show us a succession of different views. But this result can easily be explained: when we are in front of the print, the resulting image that appears projected into space is the summation of elements where each is borrowed from the median part of one of the small cellular images that occupy the full extent of the print. When we look at it obliquely, the summation is performed with elements borrowed respectively from the lateral parts of the cellular images. If these images have an aperture of 120 degrees, for example, we can sweep 120 degrees of the landscape. The perception is thereby varied because each cell carries a panoramic view of the exterior world imprinted on its back. *Tota in minimis existi natura.*

One could further increase the swept angle, up to 360 degrees, by using a convex strip , cylindrical for example, instead of a flat film. With a curved film such as the portion of a sphere or an ellipsoid, we could embrace the sky and the earth as well as the whole horizon and the resemblance of the system with certain insect eyes would be more complete.

When the direction of light propagation is changed in a dark room, rays take on the way out the same path as on the way in. As a result, the image deformations due to the imperfections of the lens have no effect; they are eliminated thanks to the inversion, and the lens, despite its defects operates as if it were perfect.

6. We now only need to meet one condition: the sharpness of the image in the back of each cell. Said differently, the ratio of its two radii of curvature should be equal to n-1. This is easy to say, but this single condition is very difficult to achieve with enough precision, given the small depth of each cell. We can only hope to address this technical difficulty with the use of a high-precision molding machine.

Collodion and celluloid are actually not the only refractive substances that can be used. Glass also enables the creation of the small spheroids forming the lenses, and we can fabricate it in unlimited numbers. However, it remains to sieve them with precision and glue them onto a collodion membrane with provides an exactly-determined additional thickness.

Commercial glass has an index that can exceed 1.9 (Schott house from Iena), but that currently does not reach 2. If it were possible to achieve n=2, the above technical difficulty, which is a geometrical matter, would be alleviated. One can indeed show that if a refractive sphere has an index of 2, the parallel rays it receives converge onto it back surface. Such a sphere, covered on half of its surface by a sensitive layer, constitutes the simplest dark room, always focused at infinity regardless of its diameter. Molybdates and lead tungstates have indices greater than 2; by mixing them with silicates, we can hope to increase the index of the mixture; but it has not been possible so far to prevent such mixture to crystallize. However, these are technical difficulties and they are not insurmountable.

Notes:

I have translated “relief” with depth but it could also be relief.