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Fooling the eyes: *trompe l'oeil* and reverse perspective

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Abstract. *Trompe l'oeil* pictures have been produced for hundreds of years. They attempt to create the impression of a surface that has different three-dimensional structure to the work; successful examples of *trompe l'oeil* typically constrain the observer's viewpoint and require use of a single eye. The works of Patrick Hughes are in relief but are painted to appear like conventional flat pictures; those parts that protrude from the picture plane are pictorially distant, or in reverse perspective. Movements of the observer result in fluid distortions of the pictorial image. These distortions occur with binocular observation and over a wide range of viewing distances.

Paintings in linear perspective have been widespread since the early fifteenth century (see Kemp 1990), and they create an allusory impression of depth to the spectator. That is, pictures in perspective are seen both as flat objects and as depicted surfaces apparently separated in depth. An illusion, on the other hand, provides a unitary impression of size or orientation that happens to contradict physical measurements (see Wade 1990). The distinction between allusions and illusions was introduced to avoid the theoretical confusions attendant on the use of the term illusion in the context of pictorial depth; there is no duality in the perception of illusions, whereas it is inherent in figurative paintings and photographs. The allusory effects of pictures in perspective derive in part from the systematic representation of visual angles, and from other fundamental characteristics of optical projection. They are referred to as monocular, pictorial, or painters' cues to depth, and they are usually given as: interposition (occlusion or overlap), height-in-the-field, relative size, familiar size, shading, and aerial perspective (see Coren et al 1999). Unlike solid objects, pictures in central perspective (like those produced by cameras) are interpreted in depth, despite their evident flatness, as a consequence of binocular observation and head movements; it is likely that we learn to interpret their allusory quality (Wade 1990).

What has been called 'illusionistic' painting is probably much older than linear perspective. Pliny, in his *Natural History*, related the story of rivalry between two Greek painters, Zeuxis and Parrhasius, in the fifth century BC: "This last, it is recorded, entered into a competition with Zeuxis, who produced a picture of grapes so successfully represented that birds flew to the stage-buildings; whereupon Parrhasius himself produced such a realistic picture of a curtain that Zeuxis, proud of the verdict of the birds, requested that the curtain should now be drawn and the picture displayed; and when he realized his mistake, with a modesty that did him honour he yielded up the prize, saying that whereas he had deceived birds Parrhasius had deceived him, an artist" (Pliny 1952, pages 309 – 311). No examples of such works have survived, which makes it difficult to assess their similarity to 'illusionistic' paintings after the Renaissance. The birds might have been better arbiters of the illusion than were the artists. Zeuxis, as a retort to Parrhasius, also painted a picture of grapes held by a child: birds still flew to the painted grapes and were not frightened away by the pictured boy. Thus, the apparent realism of the human was not adequate to delude the birds, and the attraction might

have been to colour rather than form. The artists, on the other hand, would have made judgments with regard to their experience of earlier paintings. Prior to the fifth century BC these tended to be outlines enclosing flat colours. Pliny also stated that Parrhasius "was the first to give proportions to painting and the first to give vivacity to the expression of the countenance, elegance of the hair and beauty of the mouth" (page 311).

Soon after central perspective had been widely adopted in art, in the fifteenth century, it was distorted in the form of accelerated and decelerated perspective architectures and anamorphic paintings. Descriptions of reversals of apparent depth were recorded long before the formalisation of rules for linear perspective (see Wade 1998), although most attention was paid to reverse perspective in the nineteenth century; Wallin (1905) described these studies in detail. In anamorphic art the appropriate viewpoint differs from normal or perpendicular to the picture plane, so that the pictorial content can only be seen when the picture is viewed awry or through some appropriate optical device like a cylindrical mirror (see Baltrusaitis 1976). However, one of the most pervasive forms of manipulation has been the many and varied attempts to fool the eye (*trompe l'oeil*) with flat paintings. Successful examples of *trompe l'oeil* are rare, and those that do succeed usually place constraints on the viewer. For example, Samuel von Hoogstraten's (1627 – 1678) perspective cabinet in the National Gallery (London) has a single viewing aperture on either side, and Andrea Pozzo's (1642 – 1709) ceiling painting *Apotheosis of St Ignatius* in the church of St Ignatius (Rome) defines a viewing position on the floor (see Pirenne 1970). These have been referred to as visual illusions (Wade 1990) rather than visual allusions to depth that are seen with conventional-perspective pictorial images. That is, they produce unified and compelling percept of a depth that is not present on the painted surface; the conflicting cues provided by binocular vision and pictorial framing are either not operating (as in van Hoogstraten's cabinet) or are not applicable owing to the dimensions and structure of the pictorial image (as with Pozzo's ceiling).

Thus, paintings in perspective provide an allusion to a depth not contained in their flatness—they are seen as both flat and extended in space. What would happen if a painting was produced as if it was flat but the physical surface on which it was painted was not? One of us (Patrick Hughes) has explored this possibility in works that are painted on protruding planes (like truncated pyramids and wedges) so that the parts that are physically close to the observer are pictorially distant. That is, the lines that would converge on a flat picture plane to allude to distant objects are physically closer in these works (see O'Riley 1996; Slyce 1998). They appear as flat paintings until the observer moves whereupon they undergo a plastic motion that is beguiling. The pictorially distant (but physically closer) parts move in the direction opposite head movement, whether this is left and right or upwards and downwards; the pictorially near (but physically more distant) parts move in the same direction as the head. This is the outcome that would be predicted on the basis of Gogel's (1982) experiments on concomitant head movement and perceived distance: if the perceived distance (in Hughes's works provided by pictorial perspective) is greater than the physical distance, then a retinally stationary stimulus will appear to move in the opposite direction to the head, and if apparently nearer, it will move in the same direction. If apparent motion occurs in both directions, it indicates that the apparent pictorial plane is between the veridical near and far points of the structure. In the case of Hughes's works there are few restrictions on viewing distance or position, and binocular vision makes little difference to the illusion. It is almost necessary to bump into the protrusions before they are seen veridically; once they are so seen, they remain much more stable during head movements from side to side. When standing close to the works they can switch between the two states, which could be called pictorial and veridical, and equivalent lateral head movements produce dramatically different apparent motions. In the pictorial state

the corners appear fluid and in motion whereas in the veridical state there is little apparent motion. If the eyes have retained the same convergence during these two states, then the apparent change cannot be attributed to the pattern of retinal motion during lateral head movement.

Unlike other attempts to "fool the eye" (many examples of which are illustrated in Mastai 1976 and Milman 1982), there are few constraints on viewing these works. It could be the case that we have become so accustomed to seeing flat pictures as if they were in depth that we cannot process veridically an apparently flat picture that is in (reversed) depth. A picture of a three-dimensional structure intended to be seen as a picture is not the best way to convey its perceptual allure, but front and side views of one work are shown in figure 1, so that its three-dimensional structure can be appreciated. An animated sequence made from camera movements with respect to the work *Mondrians* can be viewed on http://www.perceptionweb.com/perc0999/wade.html. Both these modes of presentation are pale imitations of the remarkable perceptual effects produced when viewing a three-dimensional work. Accordingly, a small model (*Cloudy Doors*), which can be assembled in three dimensions, can be downloaded from the aforementioned web site and constructed; alternatively, the model is available from either of the authors on request. Then lateral head movements made during observation of the constructed model will result in the perception of the fluid forms described above.

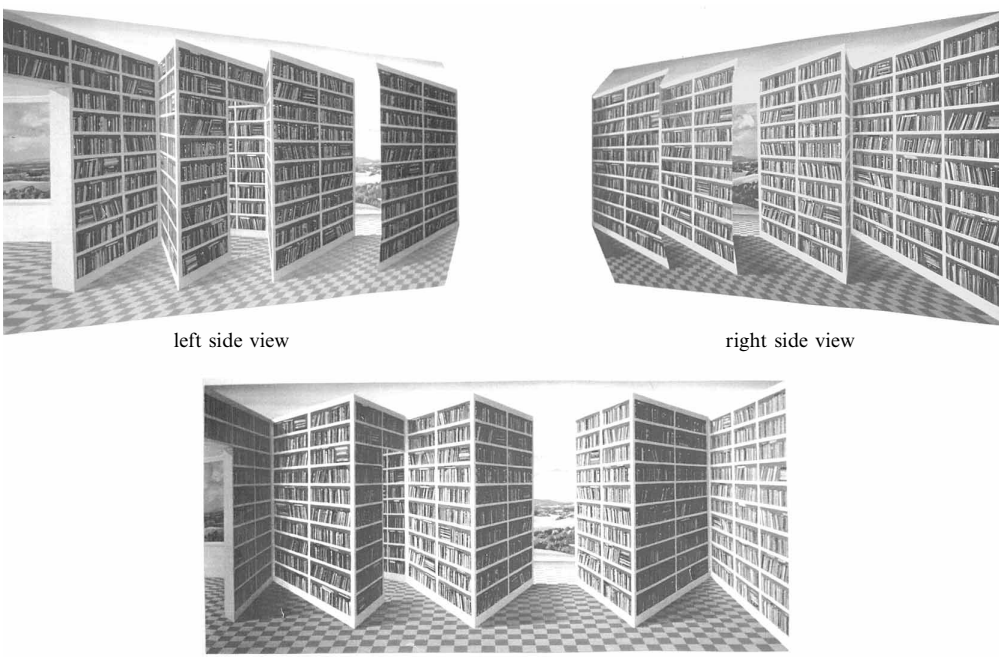


Figure 1. Frontal and side views of *Beyond the Edge* by Patrick Hughes (1998, oil on board). The frontal view (centre) appears like a conventional painting of bookshelves receding towards a more strongly illuminated room. The veridical surface structure can be determined from the left and right side views. The painted surface consists of two wedges, a truncated pyramid, and one more wedge (from the left).

Gogel (1982) produced variations in perceived distance by manipulating the disparities between the eyes when viewing an isolated source of light. Other attempts have been made to set different cues to perceived distance in conflict. One of the earliest of these was Wheatstone's (1852) observations with the pseudoscope. In order to see reversed depth

with reversed disparity "it is necessary to illuminate the object equally, so as to allow no lights or shades to appear on them, for their presence has a considerable influence on the judgment" (Wheatstone 1852, page 13). In discussing this cue conflict Wheatstone suggested that it was not under voluntary control, and also that monocular cues to depth are powerful in preventing reversal. The importance of cast shadows in depth reversals has long been known (see Wade 1998; Wallin 1905). In like manner the cues to lighting are important in Hughes's works: painted shadows enhance the distinction between the pictorial planes; if the veridical shadows cast by the protruding surfaces are prominent, then the structure is seen veridically rather than pictorially (as a flat picture).

An early example of a similar effect is Mach's (1866/1965) folded-card demonstration, although Mach was concerned principally with variations in perceived brightness rather than motion. He used a visiting card placed so that its spine was towards the viewer and with the light from one side. It can easily be reproduced if a piece of white paper is folded and viewed monocularly [see Hurlbert (1998); Wade and Swanston (1991) provide a diagrammatic representation of the arrangement]; it will eventually reverse in perspective. Mach remarked: "The light should fall from the left, and the right side will thus be somewhat darker. If I then close one eye, the sensation is almost completely unaltered. If I try to see the paper as recessed, however, I succeed after some effort. The left side thereupon appears to become much brighter and the right side much darker. Light and shade appear as if painted upon it" (1866/1965, pages 295 – 296). When the depth of the card does reverse, any lateral head movements result in marked motions of the peaks and troughs. However, the Mach card continues to oscillate in depth whereas the painted works of Hughes appear to remain stable and pictorially flat when viewed from other than very close proximity.

The most obvious parallel to Hughes's works in the perceptual literature is that by Ames (see Ittelson 1952). In fact Ames's interest in vision derived from his period as a painter. He was particularly influenced by the pointillists like Pissarro and Seurat, and endeavoured to analyse the features of his own visual impressions. In due course he became aware that his knowledge concerning the dioptrics of the eye was wanting and set about studying them in more detail. He initially thought that this would take a short time, so that he could return to painting; in fact it occupied the rest of his life (see Behrens 1993). Ames's early scientific publications dealt with the optical properties of the eye and their application to painting (see Ames 1925; Ames et al 1923). His perceptual demonstrations grew out of his analysis of aniseikonia. The Ames room is an analogue of van Hoogstraten's cabinet since they both constrain the viewing to a single location with a single eye. The Ames window, on the other hand, does not constrain the viewpoint although the perceptual oscillation is enhanced by monocular viewing.

Cues to distance have typically been studied in isolation within the visual laboratory, or set in isolated conflict (eg Stevens and Brookes 1988). The works of Patrick Hughes bring a painter's skill to demonstrate the power of painters' cues to "fool the eyes". Even though there is plentiful information for the veridical structure of the works (from binocular disparity and head movements) they are seen as flat and fluid pictures that undergo relative motions never seen in flat pictures.

References

Ames A, 1925 "Depth in pictorial art" *Art Bulletin* **8** 5 – 24

Ames A, Proctor C A, Ames B, 1923 "Vision and the technique of art" *Proceedings of the American Academy of Arts and Sciences* **58** 3 – 47

Baltrusaitis J, 1976 *Anamorphic Art* English translation by W J Strachan (London: Chadwyck-Healy)

Behrens R R, 1993 *The Man Who Made Distorted Rooms: A Chronology of the Life of Adelbert Ames Jr* (Cedar Falls, IA: University of Northern Iowa, published by the author)

Coren S, Ward L M, Enns J T, 1999 *Sensation and Perception* 5th edition (New York: Harcourt Brace)

Gogel W C, 1982 "Analysis of the perception of motion concomitant with lateral motion of the head" *Perception & Psychophysics* **32** 241 – 250

Hurlbert A, 1998 "Illusions and reality-checking on the small screen" *Perception* **27** 633 – 636

Ittelson W H, 1952 *The Ames Demonstrations in Perception* (Princeton, NJ: Princeton University Press)

Kemp M, 1990 *The Science of Art. Optical Themes in Western Art from Brunelleschi to Seurat* (New Haven, CT: Yale University Press)

Mach E, 1866/1965 "Ueber die physiologische Wirkung raümlich vertheilter Lichtreize (Dritte Abhandlung)" *Sitzungsberichte der mathematisch-naturwissenschaftlichen Classe der kaiserlichen Akademie der Wissenschaften* **54** 393 – 408. Translated in F Ratliff, 1965 *Mach Bands: Quantitative Studies on Neural Networks in the Retina* (San Francisco, CA: Holden-Day) pp 285 – 298

Mastai M-L d'Otrange, 1976 *Illusion in Art. Trompe l'Oeil, a History of Pictorial Illusionism* (London: Secker & Warburg)

Milman M, 1982 *Trompe-l'Oeil Painting* (Geneva: Skira)

O'Riley T, 1996 "The opposite of space" *Point* **3** 32 – 44

Pirenne M H, 1970 *Optics, Painting and Photography* (Cambridge: Cambridge University Press)

Pliny, 1952 *Natural History* volume 9. Books XXXIII – XXXV. English translation by H Rackham (London: Heinemann)

Slyce J, 1998 *Patrick Hughes: Perverspective* (London: Momentum)

Stevens K A, Brookes A, 1988 "Integrating stereopsis with monocular interpretations of planar surfaces" *Vision Research* **28** 371 – 386

Wade N, 1990 *Visual Allusions: Pictures of Perception* (London: Lawrence Erlbaum Associates)

Wade N J, 1998 *A Natural History of Vision* (Cambridge, MA: MIT Press)

Wade N J, Swanston M, 1991 *Visual Perception: An Introduction* (London: Routledge)

Wallin J E W, 1905 *Optical Illusions of Reversible Perspective: A Volume of Historical and Experimental Researches* (Princeton, NJ: published by the author)

Wheatstone C, 1852 "Contributions to the physiology of vision—Part the second. On some remarkable, and hitherto unobserved, phenomena of binocular vision" *Philosophical Transaction of the Royal Society of London* **142** 1 – 17

Beyond the Edge by Patrick Hughes: a 3-D model to cut out and assemble

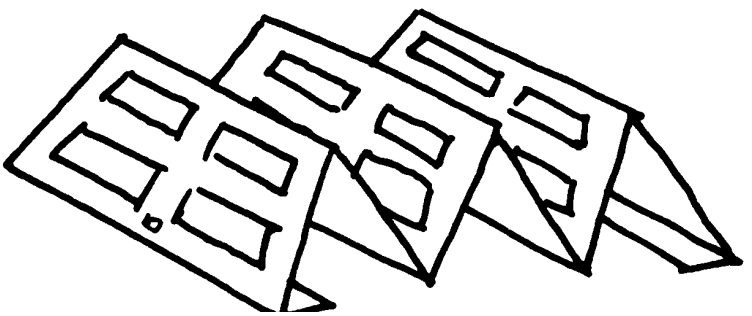
Supplement to Wade and Hughes (1999 "Fooling the eyes: *trompe l'oeil* and reverse perspective" *Perception* **28** 000 – 000)

TO ASSEMBLE

1 Print the following two pages on a colour printer.

2. Paste onto thin card (optional) and cut around the edges.

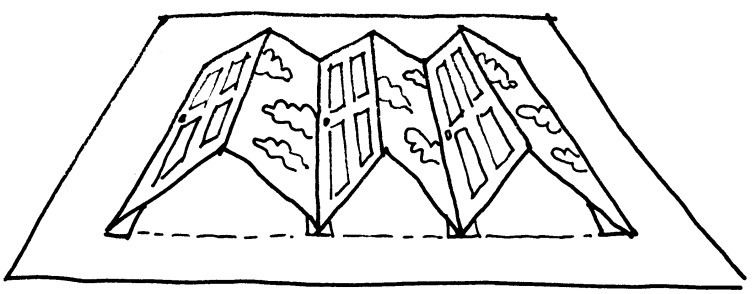
3. Crease the doors and clouds like this.



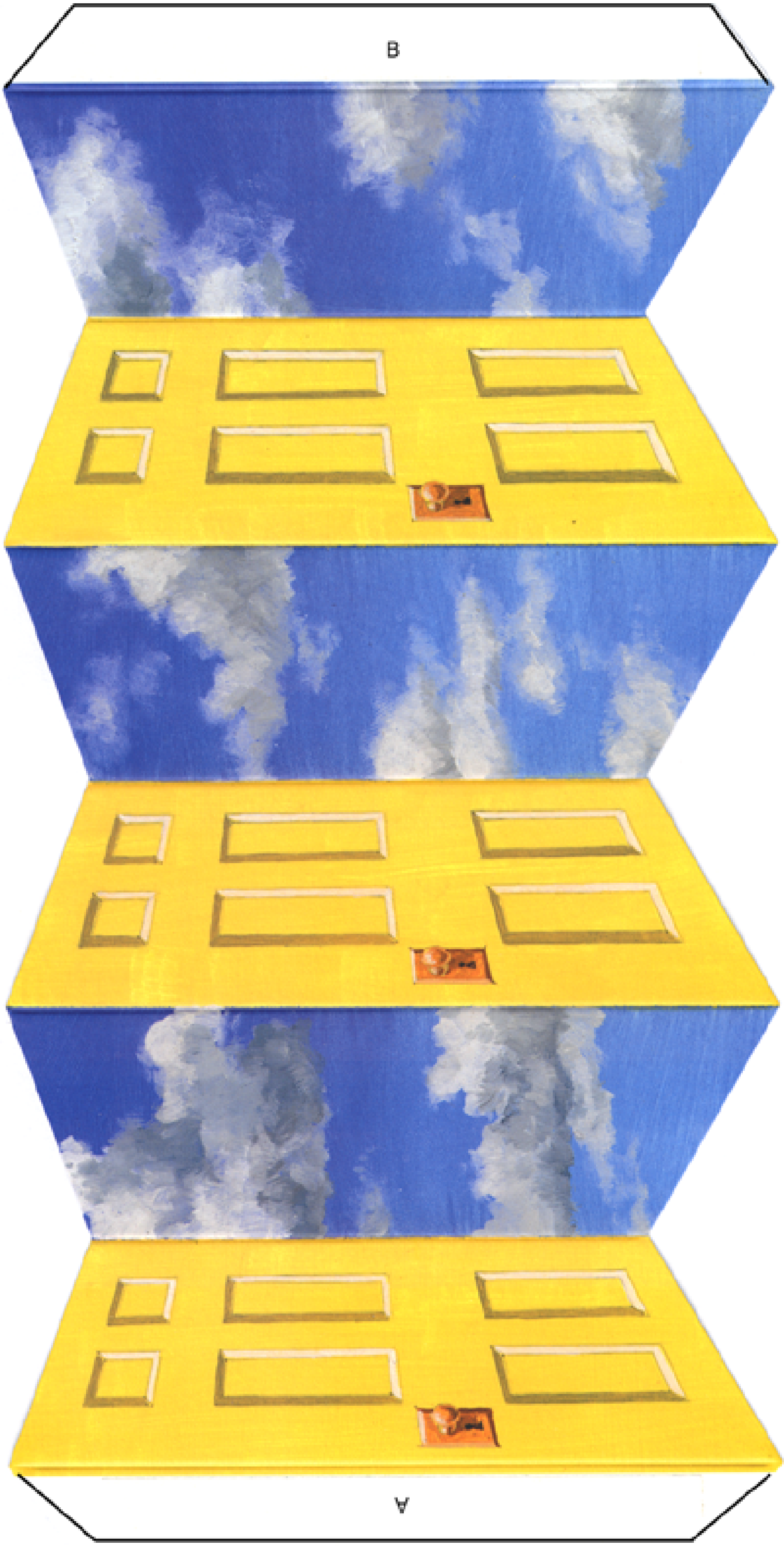
4. Place double-sided tape on tab A and position to point A on the mount.

5. Repeat with tab B to point B.

6. Place double-sided tape on the underside of the piece and firm down to create **three right angled peaks.**



Display at eye level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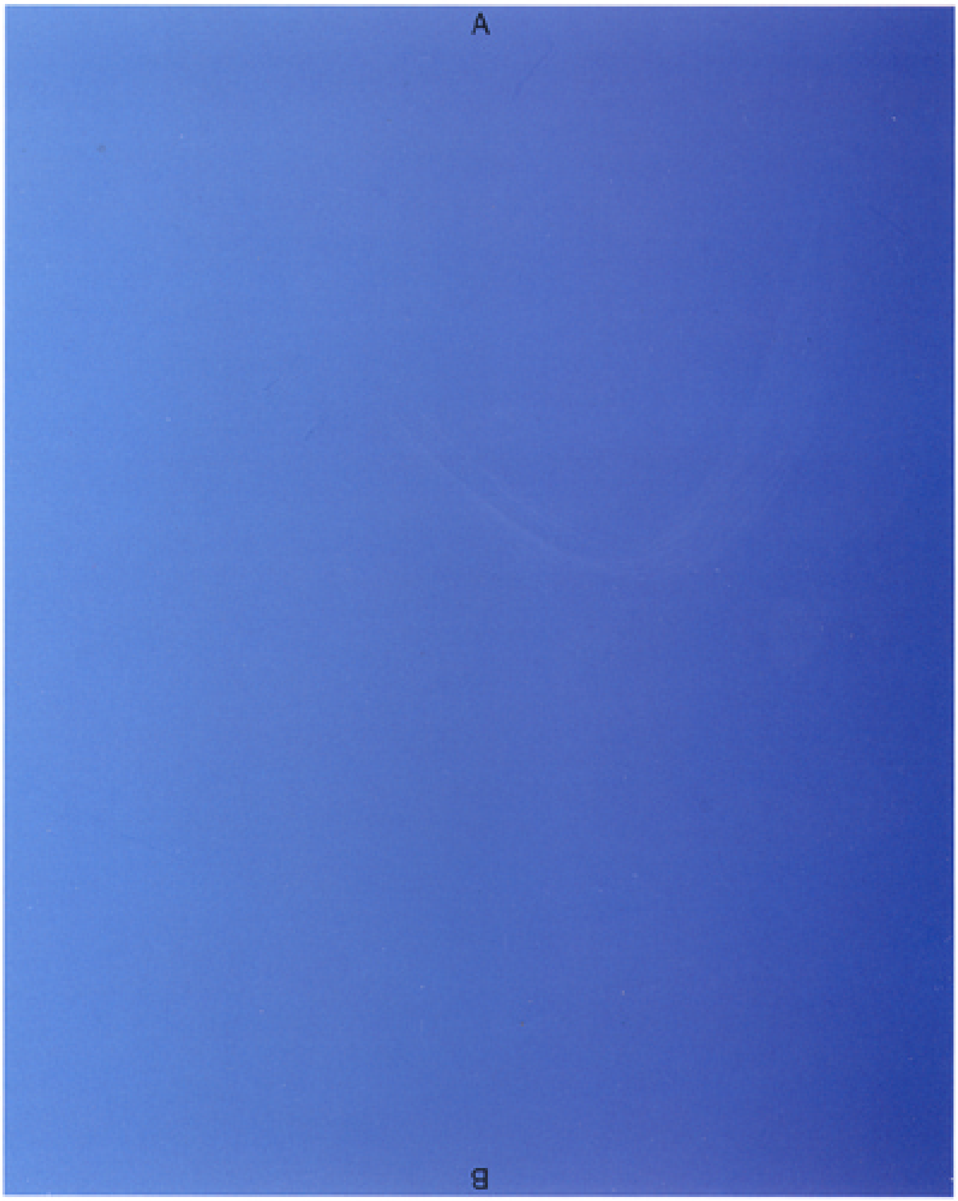
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