A direct view on our own cone cells

Entoptic structures visualized by an eccentrically rotating pinhole, or by a microscope with an eccentrically rotating aperture stop

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• What needs to be done?

Close one eye and stare at the homogenous white fluorescent screen through a 0.5 mm *pinhole* which is held closely in front of the pupil and moved along by hand (the hand being propped on the cheek) *at 3 - 6 Hz on a circular path of 4 - 6 mm diameter.*

• What can be seen?

Due to the ever changing offset of its shadows, not only the rough outline of "Purkinje´s blood vessel figure" can be perceived, but also the course of even the finest *blood capillaries*, which leave free the foveola (Fig. 1, arrow), and between them a "leather-like structure" (v. Campenhausen: Die Sinne des Menschen, Fig. 85, 1993). When watching more closely, a rather regular *pattern of tiny light dots with a smooth dark margin* can be discerned.

If you tilt a transparent *comparison pattern* - a small flock of painted dots - in front of the fluorescent screen and stare at it through the rotating pinhole, both these dot patterns are perceived simultaneously, and thus size and distance of the entoptic dots can be determined by *an equalizing procedure*: At a distance of about 1 m the spatial frequencies of both dot patterns appear to be the same. As a consequence, on the retina the entoptic dots must be about 15 µm apart.

• How does this entoptic dot pattern arise?

In the foveal region the retina consists *solely of cone cells*, which are about 15 µm in size and are closely packed, slightly offset in height (Fig. 2). As the cytoplasm of these cells is transparent, the visible dot pattern must be generated by a cellular component the *refraction index* of which differs from that of its surroundings. The *cell nucleus* is the only candidate to be responsible for this pattern: Its refraction index is higher than that of the cytoplasm and thus the nucleus acts as a *ball lens focussing the light*. We conclude that the entoptic dot pattern represents the *"shadows" of the cone cell nuclei*.

• Applications in Ophtalmology

Although this perception can, of course, not be photographed, it may serve for a *self-diagnosis during the early stages of a macula degeneration*. The growing-in of additional capillaries into the foveal region, which is caused by insufficient blood supply, for instance in diabetics, can be clearly recognized.

• Automated technique with a normal light microscope

A similar picture is created in the visual field of a transmitted-light microscope with the appropriate lens system (Fig. 3), when an eccentrically rotating aperture is mounted in the lower focal plane of the condenser. As a result the imaging light beam hits the retina from constantly changing directions and thus simulates the effect of the rotating pinhole.

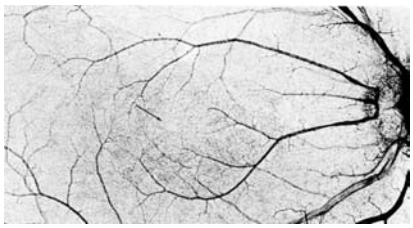


Fig. 1: *The pattern of the blood vessels which lie in front of the light-sensitive layer of the retina, a characteristic of the inverse mammalian eye. From Weiss L (Ed.): Cell and Tissue Biology. Urban & Schwarzenberg, München 1988, p. 1101 (magnification 21x for A4-printout)*

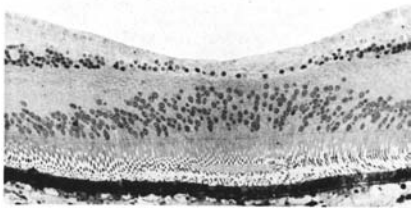
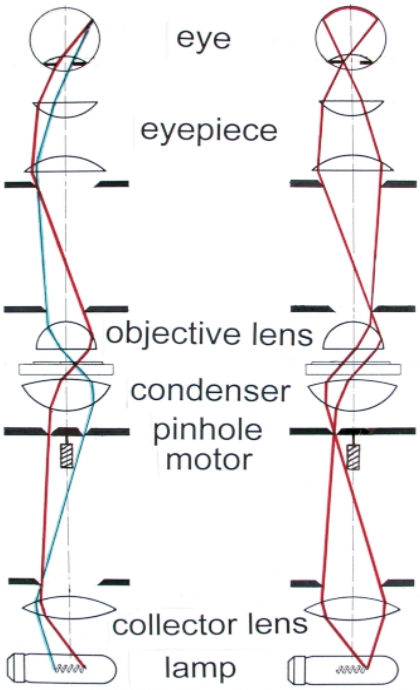


Fig. 2: *Cross-section of the foveal region of the human eye. The distribution of the stained nuclei indicates that they are the only candidates to cause shadows. Only outside of the foveola more than one cell layer is present. From Weiss L (Ed.): Cell and Tissue Biology. Urban & Schwarzenberg, München 1988, p. 1094 (magnification 37x for A4-printout)*



• What else can be observed?

1. "Fading " of increasingly retina-stable shadows

When the diameter of the circular movement of the pinhole is reduced, the shadows move too little in relation to the light-sensitive layer. As a consequence, the shadows of the blood capillaries are seen to vanish first, and then those of the cone cell nuclei.

2. Does the visual system perform a "mottle subtraction"?

With increasing viewing experience, the shadow pattern can be recognized more and more *clearly*, and despite of its low contrast even *negative after-images* can be observed. This might indicate that in normal vision our visual system "*actively ignores*" the well-known retina-stable, irritating shadows - it basically subtracts them from the incoming picture signals - similar to the well-known"Video Enhanced Contrast" (VEC) technique used in image processing of low-contrast microscopic images.

3. What we don`t perceive although the eyes "see" it

Helmholtz was the first to describe the following phenomenon: If you stare in a relaxed manner at a fluorescent screen (or even better, into the cloudless blue sky), after a few seconds you will notice hundreds of tiny "dancing dots", each of them visible for short times only (200-400 ms). The dots describe bizarre curves which cover a visual angle of about two degrees and show several changes in direction.

The psychiatrist Wilhelm Reich falsely interpreted them as "Orgone Rays": alleged "cosmic energy", which is "sucked in" by living organisms - as these low-contrast dots cannot be seen in close vicinity to objects like trees etc., whose silhouettes contrast with the sky.

As suspected earlier, the "dancing dots" are nothing but the shadows of individual blood cells which flow through the retinal capillaries, as their velocity is seen to increase when the blood pressure in the head is increased by strained breathing (information from P. Kröling; see Wolf R: Skeptiker 12:140- 149, 1999). If one watches the "dancing dots" through the stationary pinhole and then immediately rotates the pinhole eccentrically, the course of the capillaries, through which they just were squeezed, becomes visible.

Technical data of the microscope:
Eyepiece 5x, objective lens 4/0,12, condenser aperture 0.32, diameter of eccentrically rotating pinhole 0.5 mm, diameter of the pinhole path 7.5 mm, drive: moving coil DC motor (diameter 6 mm, from Conrad, D-92240 Hirschau), speed 180 to 360 rpm.
To ensure that the image of the rotating aperture stop remains inside the eye`s pupil, your face should be propped on the microscope tube with one hand, and you should stare at the centre of the field of view. On these conditions, the exit pupil of the microscope will rotate within the eye´s pupil on a circular path of about 2 mm diameter and tilt by about 6 degrees. As the distance between the light-sensitive layer and the cone cell nuclei is about 150 µm (Fig. 2), the shadows will be offset by about 16 µm, which corresponds to the size of four cones.

Fig. 3 Left: *Imaging light beam in the microscope resulting from two different positions of the rotating aperture stop. The illuminating rays of tiny aperture - painted red in one position and blue in the opposite one - hit each spot of the retina from different directions. The tilting angle is indirectly proportional to the magnification of the objective lens and the eyepiece, and directly proportional to the aperture of the condenser.*
Right: *The "pupil optical path" shows that the visual field remains equally bright, irrespective of the position of the pinhole.*