A PECULIARITY OF VISION IN ANIMALS WITH SLIT-LIKE PUPILS

BY

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How the world looks to the other fellow is a question of no small interest but one which can never be completely answered. With human eyes the ophthalmologist has gone far, however, in expressing the effects of differences in retinal structure and the effects of slight differences in size and form of the refracting media. Most of the methods employed necessitate an intelligent cooperation on the part of the subject and hence a greater barrier is at once introduced with respect to work with the lower animals. Even here, however, a consideration of the anatomical features together with the optical principles involved can lead to many reliable conclusions as to the nature of vision.

In the cat and a number of other animals the pupil of the eye is slit-like in shape[1], while the eye is in other respects quite similar to our own. In the cat the pupil is a vertical slit which in bright light becomes so narrow as to be almost closed and in dim light dilates to a true circle. In the horse and the goat the pupil is oval and horizontal.

It was long ago suggested that an advantage to the cat in enlarging its pupils was, aside from admitting more light, to widen the angle of vision.[2] This would imply that when the pupil was slit-like, the field of vision would be narrowed horizontally. Indeed, a popular explanation at the present time is that the cat has a long vertical field of vision to enable it to more easily hunt its prey up and down trees, while the horse, being a grazing animal, is benefited by being able to see objects over a wide expanse to the right or left.[3]

A consideration of various aspects of the question seems to indicate that probably the relation of the shape of the pupil to the angle of view is not so prominent as has been supposed, unless possibly when the slit is very narrow. It must be remembered that the iris in the eye lies in close proximity to the crystalline lens and does not act merely as a window to limit the field of view but acts as a true entrance pupil limiting the zone pencils to certain areas of the lens. It is true that the *effective*

[1] Geo. Lindsay Johnson, "Contributions to the Comparative Anatomy of the Mammalian Eye." Philosophical Transactions (London), Series B, *194*, 1 (1901).
[2] William Porterfield, "A Treatise on the Eye," Edinburgh (1759).
[3] Thomas Hall Shastid, "Our Own and Our Cousins' Eyes," booklet published by the American Optical Co., Southbridge, Mass. (1926).

pupil, being the image of the actual pupil formed by the cornea and aqueous humor, is slightly ahead of the actual pupil and it limits the field, but in any case the field is very wide as far as illumination is concerned. It is the definition which falls off rapidly for increasing angles of obliquity so that vision becomes very poor long before the margin of illumination is reached on the retinal surface.

In man and doubtless other of the higher animals, distinct vision is limited to a field within a very small angle from the visual axis, and the entire image of this limited field falls within the fovea of the retina. Of course the broader field is also important in aiding the visual perception since it brings into consciousness the presence, position, and movements of prominent objects over a wide area, but for seeing distinctly, the eye is rotated until the image falls upon the fovea.

Another effect of a slit-like pupil has to do with spherical aberration. This does not appear to have been previously considered with reference to vision. In Figure 1 is illustrated the effect of spherical aberration with a lens in which only a slit-like area is employed. With an object at O, consider I_2 to be the position of the focal plane for rays passing through the central part of the lens and I_1 the position of the focal plane for rays passing through the outer parts of the lens. In the plane at I_2 the image of any point on the object will consist of a blur forming a narrow vertical line from *a* to *b*. From this fact it will appear evident that vertical lines in the object will produce images with edges sharply defined, while thin horizontal lines in the object will produce images as wide as from *a* to *b* and will appear greatly confused.

If the accommodation of the eye is such as to bring the plane I_1 upon the retina as is probably done in concentrated vision upon a definite object, the effect will be less and a slight horizontal blur will be introduced. In no case can horizontal lines be as sharply focussed as can vertical lines for which the retina is in the plane I_2. As far as the experiences of the cat are concerned, the differentiation of focus of vertical and horizontal lines should be most prominent for objects which are nearer or farther than the focal plane and which are yet within the field of what might be termed subconscious vision. A natural consequence would be that the depth of focus is greater for vertical than for horizontal lines. The cat walking through a field where tall stems are prominent would get a clear conception of the vertical edges both far and near, whereas if the pupil were horizontal these same edges would appear indistinct except immediately in the focal plane and even there not quite so distinct as with the pupil vertical. The actual arrangement is doubtless an advantage in the foraging activities of the cat since it

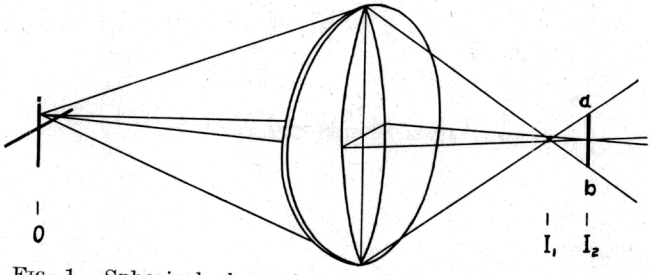

FIG. 1. Spherical aberration of a lens when only a slit-like area is used.

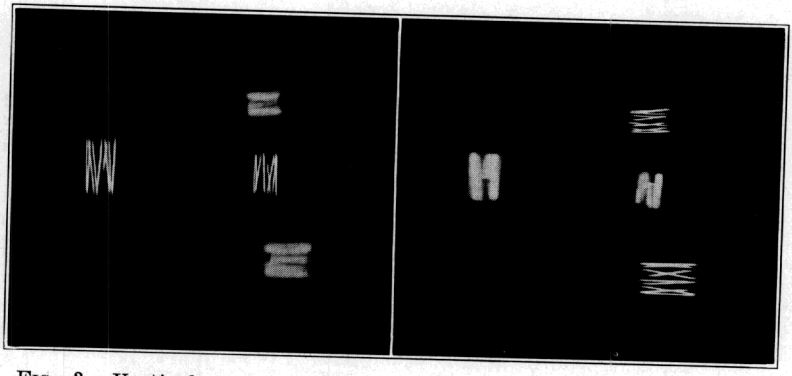

FIG. 3. Vertical and horizontal lamp filaments photographed with a lens having a vertical slit-like diaphragm.

FIG. 4. Same lamp filaments photographed with slit-like diaphragm turned to horizontal position.

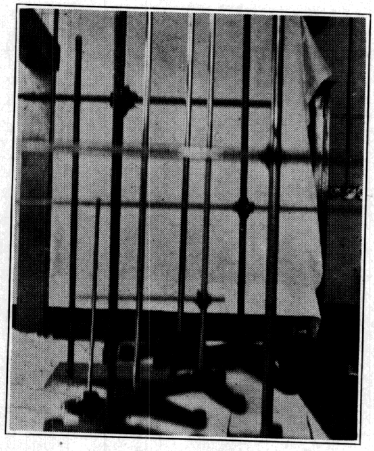

FIG. 2. Vertical and horizontal rods photographed with a lens having a vertical slit-like diaphragm.

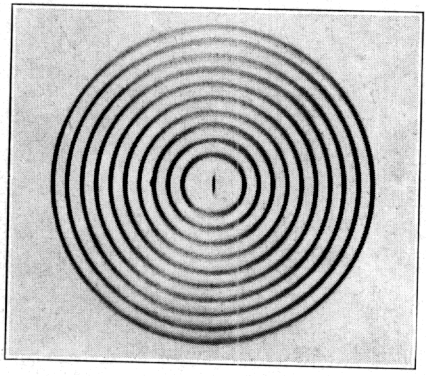

FIG. 5. Concentric circles photographed with lens having a vertical slit-like diaphragm.

allows a reduction of the light intensity to a comfortable amount and still affords a kind of vision of maximum usefulness.

The horse, with a horizontal pupil, should be able to see horizontal lines somewhat more distinctly, though the effect is probably not great, since the pupil never is so narrow as in the cat even in proportion to length. If a useful adaptation must here be ascribed, it might be suggested that since the horse's eye is ordinarily higher above the earth than the cat and he makes use of more distant vision, it would be an advantage to have a clear perception of the horizon line, also the shore lines of streams of water and the boundaries of distant feeding areas. In the image of any distant landscape, horizontal lines predominate.

To illustrate the effects under discussion, a number of photographs were made using a lens in which the ordinary diaphragm was replaced by a slit cut in a piece of black paper. For Figure 2 a set of laboratory support rods was arranged so that some of the rods were horizontal and others vertical and some were near while others were farther away. The camera lens was focussed for objects farther away than any of the rods. It will be observed that all the vertical edges appear fairly sharp while the horizontal ones are much diffused. The lens used in this and the following photographs was a Hekla Anastigmat of 13.5 cm. focal length.

For Figure 3, four incandescent tungsten lamps were set up in pairs at two different distances, each pair consisting of one lamp with filaments horizontal and one with filaments vertical. The near lamps can be identified in the figure from the fact that they appear to have the longer filaments. The lens was focussed for distant objects. Figure 4 shows the appearance under the same conditions except that the lens was turned so that the slit was horizontal. The filaments blurred in the previous photograph now appear more sharply defined.

Still another effect which is closely related to those already considered has to do with resolving power. Since the resolving power of a lens is increased with diameter of aperture it will be apparent that with a slit-like aperture, two points could be more readily resolved if on a line parallel to the slit.

The effect of a slit-like pupil placed vertically may be summarized as follows:

1. Vertical lines appear somewhat more sharp than horizontal lines, even at the best focus.
2. Accommodation for focus of vertical lines might well be different from that for horizontal lines in the same plane.
3. Depth of focus is greater for vertical than for horizontal lines.
4. Resolving power is greater for points separated on a vertical line.