THE VALIDITY OF TALBOT'S LAW FOR THE EYE OF THE HONEY BEE

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I

For the human eye an illumination which is interrupted with sufficiently high frequency appears continuous. The brightness of such a field corresponds to the objective intensity multiplied by the fraction of time during which the light reaches the observer. Consequently a reduction in this fraction is equivalent visually to a corresponding reduction in light intensity (Talbot's law).

The validity of Talbot's law for the human eye has been proved and much discussed by a large number of investigators and theoretical explanations have been proposed for it based upon the photochemical processes underlying vision (for references see Hecht and Wolf, 1931–32). Besides those upon man, data are available for *Daphnia* (Ewald, 1913), the blow fly larva (Patten, 1914), for the larvae of barnacles and *Limulus* (Loeb and Northrop, 1917 and 1922–23), for *Mya arenaria* (Hecht and Wolf, 1931–32), and for several insects (Dolley, 1923; Mast and Dolley, 1924). The data are sufficient to assume the general validity of Talbot's law throughout the animal kingdom.

The effect of intermittent photic stimulation of low frequency upon the eye of the honey bee has been pointed out in previous papers (Wolf, 1932–33*a*, *b*; Wolf, 1933–34; Wolf and Crozier, 1932–33; Zerrahn, 1933; Wolf, 1933; and Wolf and Zerrahn-Wolf, 1934–35). The bee's reaction depends in all cases upon the frequency of alternate stimulation of the ommatidia. We know that the photic response increases with the number of changes in state of excitation of the retinal elements. We found that the maximum frequency which can be perceived by the bee is about 55 per second (Wolf, 1933–34). To test the critical flicker frequency a system of sectors was rotated underneath

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the bee's creeping cage and its deviation from a straight course taken as an indication of the reaction.

If two fields equal in brightness, one illuminated constantly and the other by intermittent light, are presented to the bees and they are allowed to move freely over a longer distance toward the two fields, we can test Talbot's law by means of the bee's positive phototropic response. At low flicker frequencies the flickering field has a greater effect. If Talbot's law should hold for the bee, we ought to expect that above the critical frequency both fields have the same stimulating value, when equal in brightness.

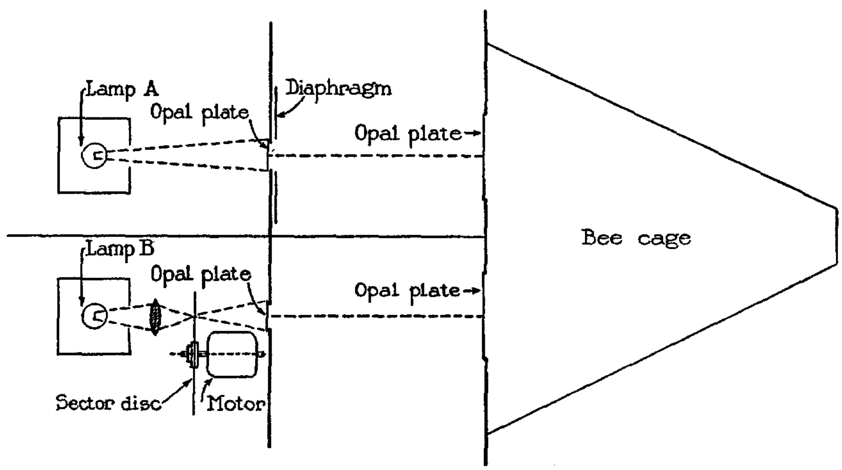

FIG. 1. Apparatus for the test of the validity of Talbot's law for the eye of the honey bee.

II

To test the validity of Talbot's law for the eye of the bee two square openings 25 × 25 cm. are cut into a wall of ply-wood (Fig. 1). The distance between the centers of the two openings is 50 cm. Into each one an opal glass plate is fitted to which the bees react phototropically, when illuminated from behind. To illuminate each field a separate light source is used, consisting of a 500 watt concentrated filament lamp. The distance of the lamps from the screens is 150 cm. To provide a uniform illumination of each field a second set of small opal plates is placed in front of the lamps, providing a larger and more easily controllable source of uniform illumination than the lamps. In front of light source *A* is a diaphragm which permits a wide range of variation in brightness of the illuminated, large opal plate. In front of source *B* sector discs are rotated by a motor at a speed of 3600 R.P.M. The sector discs used were made of sheet aluminum. Each one had two sectors cut out on diametrically opposite sides, varying in angle between 5.75 and 160°. With a speed of 3600 R.P.M. the flickering field looks to be uniformly illuminated and its brightness can easily be measured for each size of sector. For source *A* the diaphragm was calibrated and a calibration curve plotted. From this curve any diaphragm setting could be read with sufficient accuracy so that both fields could be made photometrically equal.

To the vertical wall with the two illuminated squares a cage is attached which is triangular in shape and whose apex is 170 cm. from the wall. For the test both

TABLE 1

Numbers of bees going to a flickering and a stationary field which are photometrically equal.

Flickering field				Stationary field	
Sector	*I*, millilamberts	Transmission	No. of bees	*I*, millilamberts	No. of bees
degrees		*per cent*			
5.75	0.118	2.75	28	0.118	30
11.25	0.275	6.36	24	0.275	26
15	0.352	8.14	23	0.351	27
22.5	0.519	12.01	24	0.516	26
30	0.708	16.40	26	0.708	24
45	1.14	26.33	25	1.14	25
90	2.16	49.92	25	2.16	25
120	2.95	68.25	26	2.95	24
135	3.35	77.44	23	3.33	27
150	3.77	87.29	24	3.78	26
160	3.97	91.55	27	3.98	23
180	4.32	100.00	25	4.32	25

fields are made equal in brightness. A bee is placed in the cage at its narrow end and its course observed. In each trial only a single bee is set free to avoid any mutual disturbance. The bee now moves partly crawling, partly flying toward the illuminated fields. Its course is the bisecting line between the two fields. This course is kept until it almost reaches the front wall, then zig-zag movements occur and the chances of going to the field on the right or on the left are equally high.

For each of eleven sectors we took records of the path of about 50 bees. If Talbot's law holds for the bee, we would expect that equal numbers of bees go to the flickering and to the stationary fields. This was found to be true within the limits of error for all sectors and intensities used.

The results of the tests are best presented in Table I.

SUMMARY

By presenting to bees two illuminated fields, equal in brightness, of which one is flickering and the other stationary we find that on account of the bee's positive phototropic response equal numbers of bees travel to both fields. We thus can assume that Talbot's law is valid for the eye of the bee.

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