first yellow–blue test except a small deviation to yellow, although she was more than fifty years of age; but on her second test she had an enlarged matching range and a very slight blue deviation.

The two men passed the Ishihara test, the younger making only one error. The elder made only four errors. He claimed to smoke seventy cigarettes a day. The woman, although she was less defective than the men, failed on the Ishihara test, with fifteen errors in twenty-four plates.

R. W. Pickford

Psychology Dept.,
The University,
Glasgow. Nov. 7.

[1] *Nature*, **168**, 954 (1951).
[2] *Brit. J. Physiol. Optics*, **14**, 2 (1957).

Moving Visual Images produced by Regular Stationary Patterns

It would seem that some of the intriguing visual phenomena discussed by Dr. MacKay[1] may be due, not to cerebral or retinal factors only, but at least in part to preretinal factors, namely, fluctuations of accommodation combined with lack of axial symmetry in the optical system of the eye. Helmholtz[2] described how, when looking at a pattern consisting of black and white concentric circles, and thus similar to one of Dr. MacKay's, a complicated system of darker and brighter radial zones is seen. If accommodation, or the distance from the pattern to the eye, is slightly altered, the positions of the brighter zones vary and the observer sees them rotate rapidly to and fro. According to the above explanation the phenomenon is due to actual changes occurring in the image of the pattern formed on the retina. Unless such changes can be ruled out as a factor in Dr. MacKay's more complicated experiments, it does not seem possible to conclude that subjective impressions of movement received while the pattern is looked at, or in afterimages, are necessarily caused by the nervous system responding to a truly stationary light distribution in the optical image formed by the eye.

M. H. Pirenne

University Laboratory of Physiology,
Oxford.

[1] MacKay, D. M., *Nature*, **180**, 849 (1957).
[2] Helmholtz, H. von, "Physiologische Optik", 1st ed., Part 1 (1856).

While viewing the pattern of concentric circles reproduced in *Nature* of October 26[1], many readers will have noted rapidly fluctuating sectors and they may have speculated about their cause.

This effect was first described by Helmholtz[2], but although he attributed it to accommodation, he did not give a definitive explanation of why the sectors appear to rotate.

When the young emmetrope focuses on a near test object the amount of accommodation exerted is not constant. The lens is constantly undergoing small (± 0·1 dioptre), rapid (2–3 c./s.) fluctuations of power. This has been demonstrated objectively with an infra-red high-speed recording optometer[3] (see Fig. 1). Arnulf *et al.*[4] have shown that these fluctuations are mainly astigmatic, that is, different segments of the circular ciliary muscle probably contract asynchronously. There are, therefore, even in the emmetropic eye, small, variable astigmatic errors that occur in constantly changing meridians. Inspection of Dr. MacKay's Fig. 2[1] clearly shows rotating sectors. The frequency of occurrence of the effect agrees with the objective measurements shown in Fig. 1 herewith. The reader can readily confirm that the cause of these rapidly rotating sectors is irregular fluctuations of accommodation. The rotation ceases if the eye is focused at infinity. This experiment may easily be done by viewing the pattern at 25 cm. or so through a +4 dioptre lens. Similarly, the rotation stops if the ciliary muscle is paralysed with homatropine eye drops. Naturally, the effect will not be reported by a presbyopic observer who is over the age of fifty-five years. The effect will also cease if the pattern is viewed through a 1-mm. artificial pupil, for the increased depth-of-focus of the eye eliminates the perception of the small variable astigmatic errors[5].

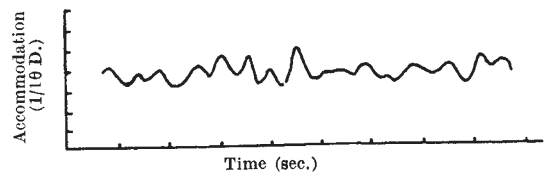

Fig. 1. Variation of power of accommodation measured in the vertical meridian of the eye during steady fixation of a small object (scale in 1/10 dioptre)

F. W. Campbell
J. G. Robson

Physiological Laboratory,
Cambridge.

[1] MacKay, D. M., *Nature*, **180**, 849 (1957).
[2] Helmholtz, H. von, "Handbook of Physiological Optics", 1, 192 (Optical Society of America translation) (1924).
[3] Campbell, F. W., *J. Physiol.*, **133**, 31*P* (1956).
[4] Arnulf, A., Dupuy, O., and Flamant, F., *C.R. Acad. Sci., Paris*, **232**, 349, 439 (1951).
[5] Campbell, F. W., *Optica Acta* (in the press).

The phenomenon mentioned by Dr. Pirenne is one of several side-effects of our patterns which are being separately investigated because they seem to be distinct from the complementary response. Helmholtz's "rotating sectors" are, of course, well known and may be considered as moiré fringes due to the superposition of displaced replicas of the pattern either in the optical image or at a neural level or both. In the 'ray' figure described in my previous communication[1] similarly fleeting 'figure of 8' moiré patterns can be seen as accommodation varies. The simplest way of demonstrating their origin is to cover the stimulus figure with a transparency of itself, when similar fringes appear (Fig. 1), and one can in fact measure the amplitude and direction of the effective retinal image-displacement by observing the displacement required in the transparency to produce the same moiré pattern.

The marked differences observed between these moiré patterns and the complementary images provided the first reason for believing that the latter had a different origin. The evidence[1,2] of interocular transfer, especially in random visual noise, and of the limited relevance of eye movement demonstrated by the persistence of the response with a stabilized retinal image and in stroboscopic light, combine to confirm that the complementary image presents a different and separable problem. Furthermore, following Campbell and Robson's helpful suggestion, I have verified that the complementary image is still seen when the ciliary muscle has been paralysed by homatropine. It can be seen also (by seven out of