nearby galaxies (Cohen, R.J. *Mon. Not. R. astr. Soc.* **187**, 839–845; 1979; Appleton, P.N. *et al. Mon. Not. R. astr. Soc.* **221**, 393–407, 1986). These observations are consistent with large-scale warps involving motion out of the plane and oppositely directed at two extremities of the galaxy.

The galaxy (NGC4013) reported by Bottema *et al.* in this issue shows a particularly spectacular warp, extending about 50 per cent beyond the optical image and very symmetrical. The warp shows up so clearly in part because it does appear to be more pronounced than any previously observed, and also because the geometry of NGC4013 and its companion is especially favourable for observation from Earth. There are two candidate galaxies that could be causing the perturbation, both at the same distance from, and on opposite sides of, NGC4013. One is NGC3938 and the other NGC4051, a well-known active Seyfert galaxy. It is interesting to note the growing view that active galaxies are the result of such interactions. The other important deduction from the new H I observations of NGC4013 relates to its invisible but massive halo. The warp actually begins where the visible stellar disk tapers off; moreover the kinematics of the H I rotation curve shows mass throughout the H I region. The warp therefore appears to lie in an extended halo of hidden matter. Undoubtedly, this exemplary galaxy will be thoroughly scrutinized as astronomers try to unravel the detailed kinematics of warping and the role of massive haloes. □

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Vision

How do birds accommodate?

Graham R. Martin

TO SEE this print clearly and then to look away and see a distant object equally well requires a change in the focal length of the eye's optical system. This accommodative change in the refractive power of our eyes is brought about by muscles that alter the curvatures of the lens surfaces of the eye. With age, the lens becomes more resistant to deformation and the ability to accommodate diminishes. But how do other vertebrates, such as birds, accommodate? After many years of doubt, David Troilo and Josh Wallman of the City University of New York[1], and Frank Schaeffel and Howard Howland of Cornell University[2] now present convincing evidence that corneal accommodation occurs in pigeons and chickens.

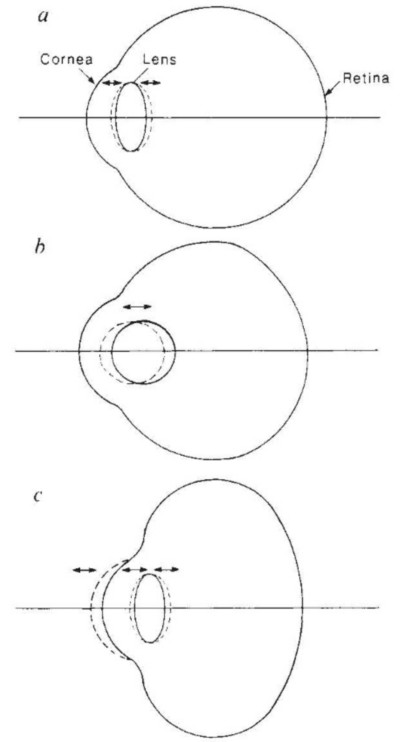
The mammalian accommodation system of changing the refractive power of the lens (*a* in the figure) is only one option for altering the power of a vertebrate eye. The optical system consists of two principal components, the cornea and the lens, and the refractive power of the whole system can be altered by varying the power of either component or by altering their separation. The latter option is the accommodative mechanism found in some fishes and also recently demonstrated in anuran amphibians[3]. In these eyes, a lens of fixed focal length is moved towards or away from the retina in much the same way that the lens within a microscope or camera can be brought to focus objects at various distances (*b* in the figure). But what about altering the refractive power of the cornea? The cornea is in essence a simple convex lens whose refractive power is produced by the curvature of its surface which separates two media of different refractive index. Increasing its curvature would increase the cornea's refractive power.

In the mammalian eye there is no evidence that this occurs; indeed there are no intraocular muscles that could bring about such a change. The bird eye, however, does contain a set of muscles that could alter corneal curvature (*c* in the figure). Crampton's muscles are anchored around the corneal margin and also to a ring of bones within the eyes, the scleral ossicles, which could provide a firm base for the muscles to pull against.

Evidence that birds do indeed accommodate by changing the curvature of their cornea was first presented as long ago as 1892 when Beer[4] observed the movements of pins placed in the corneas of a range of species including pigeon, chicken, ducks, hawks and owls. Corneal accommodation in the pigeon was described again by Gundlach[5], but by modern standards the evidence from both studies was not convincing. The problem was held in abeyance until recently, when more systematic studies found no corneal accommodation in owls, ducks and pigeons[6-8].

Unlike previous studies that attempted to induce accommodation *in vitro*, Troilo and Wallman[1] used *in vivo* electrical stimulation of the Edinger–Westphal nucleus of the chick brain which induces accommodation through the normal neural pathway and does not interfere directly with the eye. Schaeffel and Howland[2] used intact animals and monitored accommodation with a modified retinoscope and measured the curvature of the cornea with a keratometer. They induced accommodative changes simply by presenting the birds with an interesting target, such as food, at close range. Both techniques provide clear evidence of corneal accommodation and also demonstrate that in the bird eye corneal and lenticular accommodation occur in tandem, with the corneal component having a proportionately greater role in the lower range of accommodation.

Thus, accommodation in birds is now thought not only to involve a different mechanism to that of our own eye but also seems to be considerably more complicated, as it involves simultaneous alteration of the power of the eye's two principal refractive components. How coordinated neural control of these two accommodative components is achieved is clearly of interest, as is the extent to which these results apply to other species. □



Different types of accommodation mechanisms found in vertebrate eyes. *a*, In mammals, including man, the curvature of the lens surfaces is changed to increase the power of the lens only. *b*, In fish and anuran amphibians a lens of fixed focal length is moved towards the cornea, whereas in birds (*c*) the curvature of both the lens surfaces and of the cornea is altered, thus changing the refractive power of both lens and cornea simultaneously.

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