Vision

Eye development and short sight

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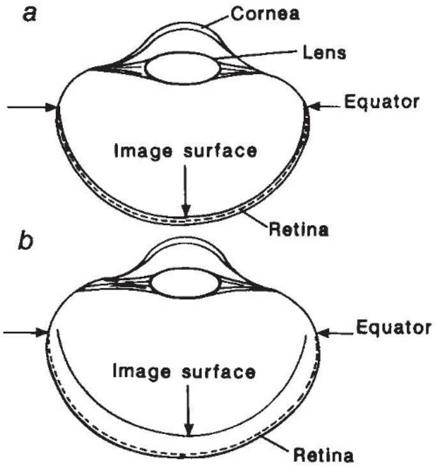
COMPARED with the complex optical structures found in invertebrate compound eyes (see the recent News and views article by Mike Land[1]), the vertebrate eye appears to be a simple affair, consisting of just two main refractive components, the lens and the cornea. But the quality of the optical image produced in the vertebrate eye is usually far superior to that of invertebrates. This quality can be achieved only by highly accurate coordination of the refractive powers of the lens and cornea and of their positions relative to each other, and to the retina. Three groups, who report their results in recent issues of *Vision Research*[2-5], are beginning to show how this remarkable coordination of the eye's optical structure is achieved, and how it can break down to produce myopia (short sight).

Not all eyes in the same species have the same optical structure. In their classic comparative study of more than 300 human eyes, Sorsby *et al.*[6] demonstrated that in those eyes judged to be emmetropic (normal eyes which when relaxed bring the image of a distant object to a focus at the retina), the eye's axial length, its corneal and lens refractive powers and its total refractive power, could vary between individuals by more than 20 per cent. These authors concluded that "the emmetropic eye is not the end result of a haphazard combination of variable components, but a co-ordinated organ. The individual emmetropic eye . . . is not accidental." They also showed that in the human eye, refractive errors, such as myopia in which the image is produced in the wrong place with respect to the retina, are usually the result of anomalous components whose values fall outside the range of normal variation. But although the coordinated development of the emmetropic eye seems to depend on normal visual experience, it was not possible to pin down what exactly underlies the apparently uncoordinated development of the myopic eye, or to determine the extent to which the development of an emmetropic eye is controlled by experiential influences as opposed to simple growth. The new research is beginning to elucidate this problem and shows just how sensitive the eye's structure is to anomalous visual input.

The new work of Pickett-Seltner *et al.*[2,3] and of Wallman and Adams[4] exploits simple techniques[7-9] which can cause a growing eye to develop a high degree of myopia. It is even possible to induce myopia in one eye of an animal and not in the other, so an individual can act as its own control. The most robust technique has been developed for use with chicks and simply involves covering the eye at birth with a translucent goggle. Pickett-Seltner *et al.*[2,3] show that a high degree of myopia is induced by this technique in chicks as young as 14 days old, indicating clearly the importance of patterned visual input to the eye for its coordinated development during this sensitive period. A high degree of myopia can even be induced by fitting chick eyes with goggles which restrict the width of the eye's visual field[7].



Chick eye with experimentally induced short-sight. In the normal eye (*a*) the image of a distant object produced by the lens and cornea lies at the surface of the retina. In an experimental eye (*b*) the equatorial diameter and the axial length of the eye are increased, and the image of a distant object now lies in front of the retina. Hence the eye is described as 'short-sighted' as only the images of objects close to the eye can be focused at the retina.

But what does the myopia induced by this technique consist of? What parts of the coordinated development of the eye are disrupted? It appears that the whole eye becomes enlarged so that both its axial length and equatorial diameter are increased but the lens remains unaffected. Changes in eye size were evident even within two days of hatching[3,4], indicating just how sensitive the development of the eye appears to be and showing that this development is dependent on the clarity of vision. Furthermore, the observed size increase in the eye appears to be the result of expansion of the globe resulting from the accumulation of fluid rather than growth of the eyeball tissue itself. The observed phenomena could be explained in part as the result of an inflammatory response of the eye to goggle wear[10], but the new work suggests that this is not the case[2].

Even more intriguing is the finding that this experimentally induced myopia is reversible if the visual restriction is removed during the first 6 weeks of life[4]. If pattern vision is restored during this period, then the eye will become emmetropic with the rate of recovery from myopia directly related to the degree of myopia induced. These results all suggest there is a feedback mechanism which regulates eye growth and which is influenced by the quality of the image present on the retina.

Frank Schaffel and colleagues at Cornell University[5] have now taken the technique one step further. Instead of simply inducing myopia by the use of translucent goggles, they raised chicks with lenses in front of their eyes which slightly defocus the image on the retina. The refractive powers of the lenses used are large enough to blur the image in a normal emmetropic eye but are within the range such that their optical effects can be compensated by the natural accommodation of the chick eye. Schaffel *et al.* show that growing chicks can indeed keep the images on their retinas in focus when wearing the lenses. But when the lenses are removed after between 17 and 26 days, the eye is permanently out of focus — it has developed to take account of the refractive error forced upon it by the lens. As in previous studies, Schaffel *et al.* find that it is eye length that has changed, just sufficient to bring the image and retina into approximate coincidence. Also, as previously, they find the refractive components of the eye are unchanged and the effect occurs independently in each eye.

The dependence of the developing visual areas of the brain on normal visual input has been well established. These new results suggest an intriguing developmental feedback mechanism between the neural retina, where a patterned image is detected, the optical system which produces that image, and growth of the eye. These simple techniques which experimentally induce myopia hold out the promise not only that the mechanism underlying the development of myopia may be understood, but also that the finely coordinated development of the normal eye's optical system might be elucidated. □

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