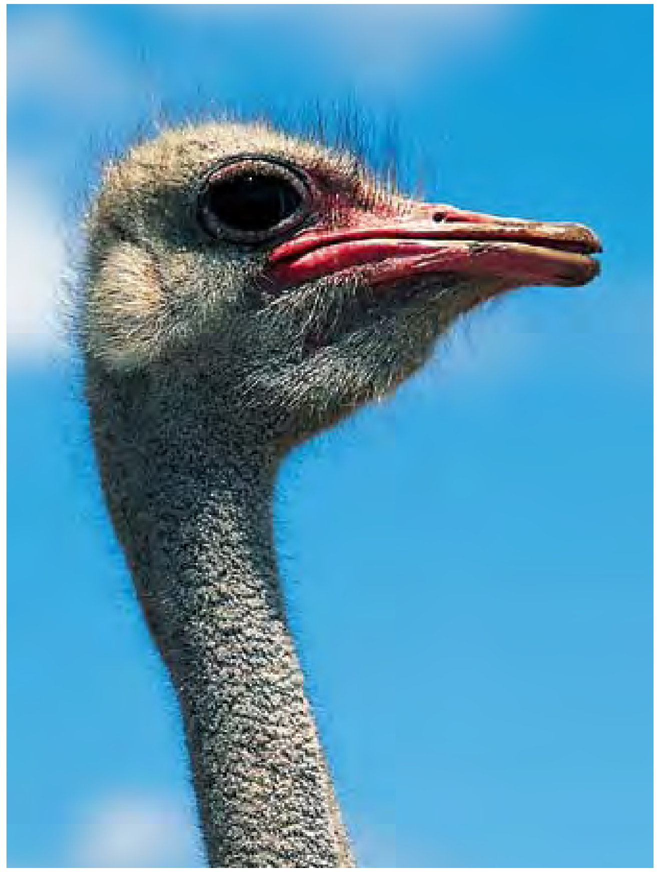
It has been suggested that the popularity of birding, at least in part, stems from the similar ways in which man and birds perceive their environment: it is much easier for us to relate to a bird's view of the world than, for example, to a mole's view. A bird's view of the world, however, has long been recognized as being considerably more acute than ours. Expressions such as 'eyes like a hawk' are widely used, but analogies are rarely, if ever, drawn between human eyesight and that of any other mammal.

It is fairly easy to understand why acute vision is of such benefit to birds – theirs is an intensely visual world. Finding food and mates, avoiding predators and flying through structurally complex habitats such as forest, all rely on excellent eyesight. Simple evidence for the importance of vision in birds is provided by the size of their eyes: proportionally, they are much larger than those of mammals. In absolute terms, our eyes are about the same size of those of a large owl or raptor. The Ostrich claims a unique optical record – its eyes are larger than those of any other terrestrial vertebrate! But having large eyes is not in itself adequate to explain why birds see so well; to do this, we have to delve deeper into the positioning, shape and structure of the eye itself and examine some of those features that make it such a masterpiece of evolutionary design.

## The hunters and the hunted

The positioning of the eyes in the head differs between different bird species. In some, such as owls and birds of prey, the eyes are positioned towards the front of the head. In others, including many ground-feeding birds such as doves, the eyes are positioned on the side of the head. These two different designs serve different functions. Birds which hunt fast-moving prey must track their prey during the chase. To be successful, they need accurate perceptions of speed and distance. These are achieved through binocular (or stereoscopic) vision, that is, both eyes are locked on to the object simultaneously and their movement is synchronized. In this way, birds perceive a three-dimensional image (in the same way as we do). Whilst excellent for hunting, this does limit their field of view – owls, for example, have to rotate their heads in order to see behind them.



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*The Ostrich claims a unique optical record – its eyes are larger than those of any other terrestrial vertebrate.*

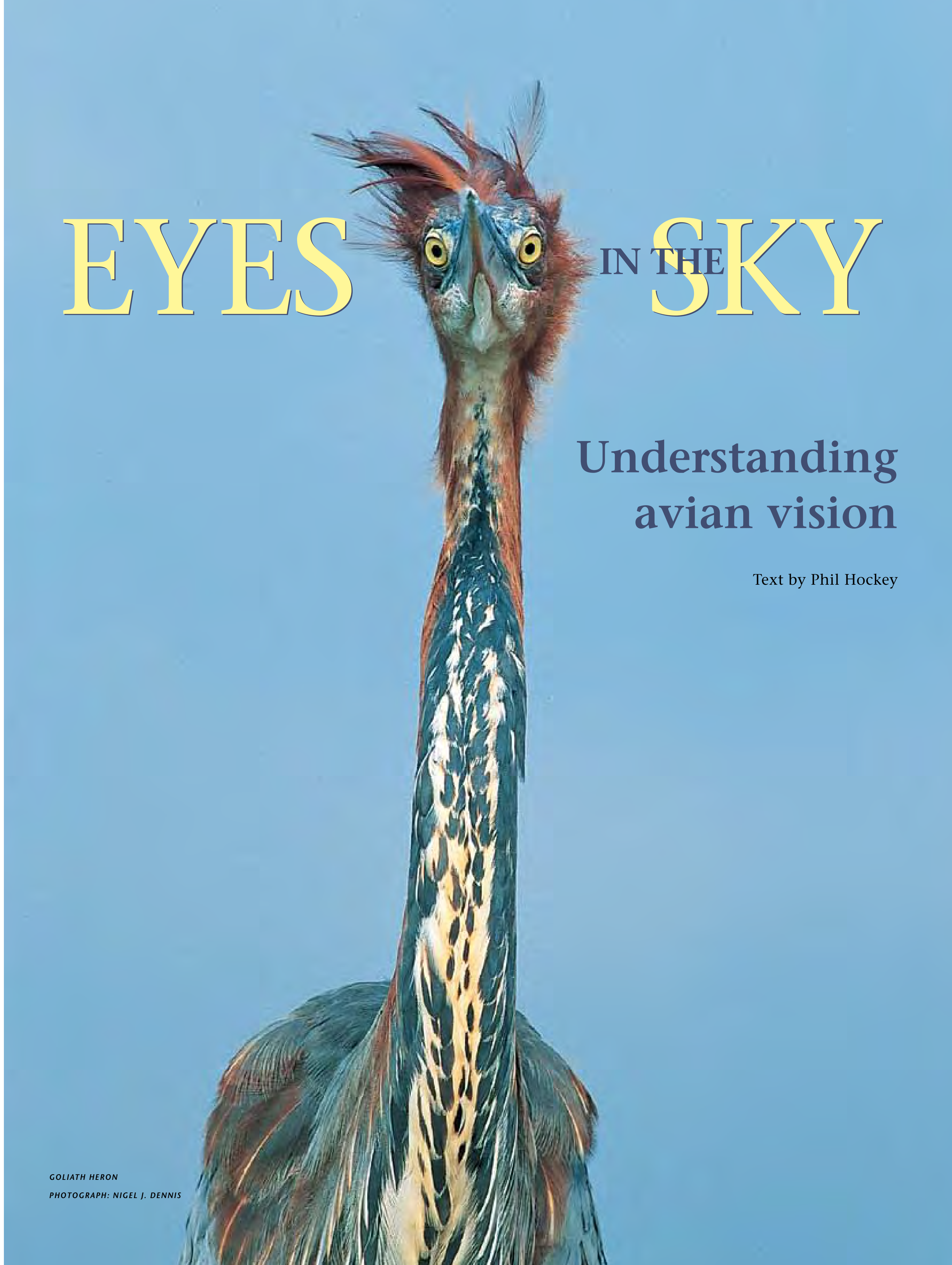
Birds with laterally positioned eyes have a very large field of view – more than 300° in pigeons – but gain this advantage at the cost of having a much reduced field of binocular vision. A wide field of view is, however, of great value in detecting approaching danger.

## Projection screens and focusing mechanisms

The shape of the mammalian eye, including our own, is one of evolution's less successful designs. Because it is essentially spherical in shape, only a small part of the image falling on the retina is in focus. The problem is akin to trying to project an image from a slide projector on to a strongly concave screen. A bird's eye, by contrast, is flattened at the back, forming a much more even 'screen' on which the entire image is in focus, not blurring towards the periphery. Not only does a bird's eye have a more high-tech screen than ours, but birds also have far greater focusing ability. They can change their focal distance very rapidly, and can also achieve focusing 'tricks' that we could only manage with extremely strong glasses.

Consider, for example, birds which hunt for their food in water, such as cormorants and some of the kingfishers. As you move from air to water, refraction increases by some 20 diopters. We would normally wear glasses to correct for a deficiency of one diopter, and the glasses you would need to correct for 20 diopters would be so thick you would probably need a neck brace to wear them! The underlying secret to this ability in birds is that the lenses in their eyes are very much softer than those of mammals and therefore their shape can be changed more easily. When light enters the eye, it passes first through the cornea (the clear outer wall of the front part of the eye) and then through the lens. Both the cornea and the lens change the direction of the light rays, but it is primarily changes in the shape of the lens that effect focusing. Both bird and mammal eyes have muscles that press up against the lens, changing its shape and bringing about focusing. In mammals this is the only real option available for focusing, but birds have others. They can also change the shape of the cornea by using muscles which drag the edges of the cornea backwards, thus increasing the curvature in the middle.

We are unable to do this, although the principle of changing the cornea's shape underlies the radial keratotomy operation used in correcting short-sightedness. The third focusing technique used by birds is employed under extreme conditions, such as underwater, and brings the iris into play. The iris is a muscular ring that opens and closes like the aperture of a camera to control the amount of light passing into the eye through the lens. By holding the iris rigid, and using the muscles adjacent to the lens, the soft lens can be forced to bulge ▷



# EYES IN THE SKY

## Understanding avian vision

Text by Phil Hockey

GOLIATH HERON
PHOTOGRAPH: NIGEL J. DENNIS

*Over evolutionary time, the avian eye has developed a plethora of special and unique features which make it one of Nature's finest designs.*

PETER STEYN

through the opening of the iris, achieving extreme curvature. The more rigid lens of a mammal precludes this focusing option.

### Receiving the signal

When light enters the eye and falls on the retina, an image is perceived and decoded by the brain. The retina thus acts as an interface between the outside world and the biological computer, the brain. Light falls on to, and triggers, nerve cells in the retina. The signal is passed from the retina along a nerve chain. There are two types of light- or photo-sensitive cells in the retina – rods and cones. These differ in the circuitry through which they pass messages to the brain. In the case of rods, several converge on a single nerve chain to the brain. This design increases the strength of the signal through a multiplier effect. Cones, by contrast, each have their own dedicated line to the brain. Because the strength of incoming light determines the strength of signals sent to the brain (which is why your eyes hurt in bright light), cones are most effective under good light conditions – sending very clear images to the brain – and rods work best under low light conditions – amplifying the signal but losing some of the definition. Nocturnal birds have retinas rich in rods, and diurnal birds have retinas rich in cones.

Above *The large, frontally positioned eyes of owls provide them with excellent stereoscopic vision. Because these birds hunt primarily in low light conditions, their retinas are rich in rods. The Spotted Eagle Owl shown here is a typical example.*
Below *Eyes positioned on the side of the head, as in this Namaqua Dove, do not work well for stereoscopic vision but can detect the approach of danger from almost any quarter.*

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### High-quality reception… and magnifying glasses

Mammals also have rods and cones in the retina, so these alone are not a reason for birds' excellent eyesight. Their greater efficiency in birds can only be understood in conjunction with the way in which the eye receives nutrition (without which it could not function). The mammalian retina is richly supplied with blood vessels. These take up space and therefore compromise the number of rods and cones that can be accommodated in the retina. There is no blood supply to the avian retina, so that it can be dedicated entirely to receiving and passing on light signals. Nutrition is provided to the bird's eye by way of a small, blood-rich structure called the pecten. So as not to disrupt picture reception, the pecten is anchored to a small area of the retina called the optic disc: this is where the nerves from the photo-sensitive cells come together and leave the eye *en route* to the brain. There are no rods or cones at the point where this nerve cable leaves the eye, so vision is not impaired. In both birds and mammals, there is a small area in the middle of the retina that is thicker than the rest. This is a region particularly rich in cones and is unimaginatively termed the 'central area'.

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Above *Birds which hunt their prey under water, such as this Pied Kingfisher, must be able to cope with 20 diopters of refraction – much more than the human eye can handle.*
Below *A Lesser Double-collared Sunbird feeds at an erica. Birds can probably sense ultraviolet light and may use this ability in the same way as nectar-feeding insects to detect ultraviolet 'nectar-guides' on flowers.*

PETER STEYN

In birds, the central area may have a depression within it (called a fovea). This acts as a small magnifying glass, and projects a slightly enlarged image on to the retina. Some birds which pursue prey at high speed have two foveas in each eye – these are thought to help in stereoscopic vision.

### Colour vision and beyond

Many birds are brightly coloured and frequently use these colours in social and other displays. This in itself is good evidence that they have colour vision. The colour image is provided by visual pigments in the cones. In addition to these, however, birds also have brightly coloured oil droplets incorporated in their cones. It is thought that these work not in producing a colour image *per se*, but by acting as filters to enhance contrast in the same way as photographic filters do. Thus, yellow droplets would remove much of the blue from the background, enhancing contrast between an object and a blue sky. Red droplets would remove much of the green, which would help birds searching for insects in a forest.

Unlike us, birds are sensitive to ultraviolet light. They also seem to be able to detect polarized light, and this ability may be particularly important in navigation. The pattern of light polarization in the sky changes during the day as the sun's position moves. This may well help migrating birds which use the sun's position as a compass – especially on overcast days.

At the beginning of this article, I stated that birds were highly visual animals. Over evolutionary time, the avian eye has developed a plethora of special and unique features which make it one of Nature's finest designs. Perhaps we are correct in drawing the analogy between the way in which man and birds perceive the environment, the difference being that birds see it with a clarity we could only dream of!

*Many birds are brightly coloured and frequently use these colours in social and other displays. This in itself is good evidence that they have colour vision.*