Good or bad design of the eye of vertebrates?

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The eye is the most important sense organ for primates, including us humans. Other vertebrate animals rely most on other senses: those of the dog family, wolves and other social pack-hunters, use mainly their extraordinary sense of smell to detect and follow prey, rather than their vision. Birds generally have a limited sense of smell but their ability to spot small prey animals from far away is very acute.

This organ, so important to us, has inspired the development of ideas about how life evolved. Charles Darwin struggled to explain how the complexity of the eye could have arisen. At the time he was working there was insufficient knowledge of a chain of intermediate stages leading to the evolved design of the eye of vertebrates. Another aspect of studies on the evolution of the eyes of vertebrates is the idea that the design is poor when compared to the optical performance of a camera made by humans. If the naturally evolved design of a vertebrate's eye is poor, then it cannot be the work of an intelligent designer in the form of a deity. Not only is the vertebrate eye compared unfavourably to cameras but also to the eye of squids and octopuses (cephalopod molluscs).

It seems to be the problem with the vertebrate eye is that the structure that senses light, the retina, is the wrong way round! The cells sensitive to light, the photoreceptors, face away from the incoming light. Bad design? Seems to be, moreover the photoreceptors are covered with layers of nerve fibres and blood vessels.

The best studied eye is of us humans, with a vast literature written for and by eye surgeons and opticians. A human embryo starts to develop eyes during the first few weeks of life. The retina in particular forms as a bulbous outgrowth of the brain and will remain an essential working part of the brain in adults. These bulbs each fold in on themselves, they invert by a process of differential cell growth. The inverted bulb comes to have two layers and it is the nature of the embryonic brain that it is the inner surfaces of both these layers that develop the capacity to form a retina with a layer of photoreceptors pressed against a layer of cells that support the physiological needs of the photoreceptors.

In contrast to vertebrates, octopuses and squids have their photoreceptor layer facing towards the lens of the eye, and with the nerve fibres going beneath this layer as they lead from the retina to the central brain. That works well: these invertebrate molluscs have good eyesight for hunting prey. But is octopus vision really better than human vision?

Some families of vertebrates show the highest development of vision of all animals. Think of a hawk high in the sky searching for a flicker of movement by a mouse in the grass. We primates evolved for a life in the trees, using our full 3-colour vision to search for ripening fruit and our binocular vision to swing with ease amongst the branches.

As for cameras – they are an aid to human vision. Reading glasses are a simple optical aid to the vision of a human who has become, with age, long sighted. Glasses are inert things, objects without meaning unless used by a human. A camera of powerful design mounted on a satellite or spacecraft is similarly without meaning or function unless information from it provides, as images or sequences of 0s and 1s, is used by people. Cameras and similar tools are in a separate domain from living structures. Comparing them with living things, human or octopus, is an error of logic, a category error.

The vertebrate eye seems to work so well because of the inverted retina, not despite it. The barrier of the nerve cell layer and retinal blood vessels to high definition vision is solved by the fovea region of the eye where light is naturally focussed. The layer of nerve fibres is as thin as possible and the inner blood vessel layer is absent here. The tiny spot of the fovea works in combination with constant tiny movements of the eyeball called saccades. These are imperceptible to us as they dart about to concentrate our attention on. The immense power of the nerve cell layer of the retina to pre-process visual information helps to create a coherent impression within our central brains of the objective world. The centre of our view appears in sharp focus whilst our peripheral vision, supplied by the rest of the retina, provides the context and warns of hazards approaching sideways.

The biochemical business of photoreception for full colour vision in bright sunlight through to the ability to grope our way by moonlight is enormously demanding of nutrients, oxygen, and disposal of waste carbon dioxide and metabolites. The retina of humans has been measured as having the highest oxygen demand of any tissue in our bodies. Even in the dark it works hard to keep the photoreceptor cells in readiness and good health.

To supply the retina there is an extraordinary blood system called the choroid. This is a network of small blood vessels that is dense laterally and about three layers deep. It envelopes the outside of the eyeball and presses closely against the outermost retinal layer. The blood vessels have special gaps in their walls, permitting an exceptionally high rate of exchange with the retina. This entire adaptation for vision of dense information content is physically possible only with an inverted retina. Molluscs do not have this structural adaptation for vision.

Using the vertebrate eye to illustrate arguments for intelligent design, or for design by natural selection, seems to be on shaky ground for both sides of the argument. These argument are tired and long outdated anyway. The modern perspective is that life is full of compromises. Evolution throws up many contrary features and problems with design. The list of features of animal anatomy and function that reveal accidents of evolutionary history is long. Just one example will do here: the eye, of humans at least. The two layers our retinas are liable separate from each other. There are no anatomical or cellular connections to hold the layers together, only the thin liquid between them acts by surface tension as a glue, amongst other functions. The repair and prevention of retinal tears and detachments is an important part of the work of eye surgeons.

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