The Eye's Grand Design

Remodeled history can be a beautiful thing. The centuries-old campus where I teach holds dozens of examples of historic buildings that have been refurbished, remodeled, or expanded to meet the needs of a modern university. When these projects work, they have a character that newly-designed structures, with their unified architectural themes, simply lack. You enter a modern lecture hall through a lobby built before the Civil war, you gaze upwards through an old skylight opening into a glittering new atrium, or you step into an office where one wall, inexplicably, is made from weathered, rough-hewn brick. That brick, of course was once the outside of the building, now part of an internal wall after the old structure was repurposed. There's a new outside wall now, but the old design still shows through, perfectly functional in its new role in the interior of a modified building.

The reuse of old structures and old designs isn't confined to architecture, of course, it's something that living organisms do all the time. As paleontologist Neil Shubin put it in his wonderful book "Your Inner Fish," our hands are actually remodeled fins, our heads are organized like those of long-extinct jawless fish, and even our genes are remodeled, repurposed versions of those found in mice, worms, and yeast.

Our eyes, those intricate and complex organs through which we perceive the outside world, are perfect examples of the remodeling of an old structure to fit new needs. The retrofitting architects, of course, are those hard-working guys from the well-known firm of "Evolution by Natural Selection," Charles Darwin, founder.

The vertebrate eye is a multipart organ that gathers light, adjusts to its intensity, and focuses it on a complex array of light-sensitive cells known as the retina. As you ability to read these words demonstrates, the retina does its job brilliantly, but like an old building brought up to date by a retrofit, it still reveals its ancient roots.

The retina evolved as an outgrowth of the brain itself. The fibers that connect individual neurons run along the cortex, the surface of the brain, and that is also true for the cells that gave rise to the retina. What this means is that the basic architecture of the retina is actually inside-out with respect to the light-sensing function it acquired during the course of evolution. Light must pass through layer after layer of nerve fibers and interconnecting wiring in order to reach the light-sensitive rods and cones beneath. No designer of optical systems would place that wiring above these sensors, any more than a modern architect would design a building, from scratch, to look like one of the repurposed structures on my campus. Yet that's exactly what our eyes are like. They betray their evolutionary history.

Natural selection, to be sure, has worked on the retina in remarkable ways, some of which we are only beginning to understand. For example, in the fovea, the most sensitive portion of the retina, rods and cones are packed to a very high density, and the neural wiring is pushed off to the side so it cannot scatter the incoming light. This is why we have to look directly at an object, focusing its image on the fovea, in order to see all of its details clearly.

It's now clear that there's another way in which the retina's wiring has been modified to get around the problems presented by its basic architecture. The retina contains a group of long, cylindrical cells known as Müller cells that help support other cells in the wiring above the rods and cones. A 2007 study headed by Dr. Joachin Guck of Cambridge University revealed that Müller cells may act like optical fibers, guiding light through the maze of interconnecting neurons to help it reach the light-sensing layer with only minimal scattering. In the words of the study, Müller cells have a "peculiar ultrastructure" that suits them to this task. The cells have few organelles that might scatter light, and contain thin filaments that help to guide and orient incoming light. The researchers note that the light-guiding capacity of these cells "make them ingeniously designed light collectors," and indeed they are. The shape, orientation, and internal structure of the Müller cells help the retina to overcome one of the principal shortcomings of its inside-out wiring.

What these discoveries don't mean, much to the consternation of the so-called "intelligent design" movement, is that the vertebrate retina was produced by an actual designer who drew up its cellular plans on a cosmic drafting table. The Müller cells, much like the fovea itself, are a retrofit, a successful and highly functional adaptation made necessary by the original architecture of the retina. If the retina weren't inside-out to begin with, these cells wouldn't have to guide light through the tangle of neural wiring, the eye wouldn't have to concentrate high-quality vision at a single point like the fovea, and it wouldn't have a blind spot, where its wiring pokes a hole in the retina to send signals to the brain.

The fact that a repurposed and refurbished historic building is beautiful, functional, and even elegant doesn't obscure the basic facts of its history. It's an old design adapted to new circumstances, even if that adaptation, like the eye, is a work of functional brilliance.

Kenneth R. Miller
Professor of Biology
Brown University
Providence, RI 02912
USA

April 27, 2010