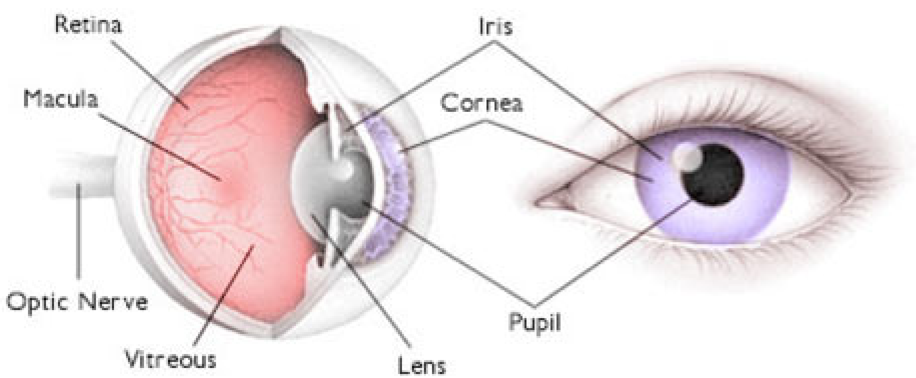
The Photographic Eye

How Our Eyes See vs. How Our Cameras See

By Allan Weitz (from B&H Photo Video)

The human eye, with support from the brain (the fastest CPU on the planet), visually reconstructs our surroundings in real-time as we go about our days and nights. Describing the human eye and how it interprets the world around us in terms of camera optics is a tricky process to explain, and that's before we even get to the 'how does it compare to my camera' part of the story.



The camera-like features of our eyes include the cornea (which serves as the focusing mechanism and a 'UV filter' to protect the 'lens' surface), the iris (the round blue, green, brown, or hazel part of your eye that dilates wider or smaller depending on the f/stop required), the pupil (or lens), and the retina (the de facto film plane / sensor surface that lines the rear inner-surface of the eye).

The image we actually see is upside-down and backwards (like a view camera), but is 'corrected' by the portion of the brain responsible for turning things right side-up and forwards. Newborns see the world uncorrected, which is why they sometimes glance or reach in the opposite direction of the movement they are trying to follow.

Experiments with adults wearing glasses that revert vision back to its uncorrected state show that they adapt to the reversed perspective quicker than you'd imagine. Once acclimated to these glasses, the test-subjects become equally disoriented when the glasses are removed.

A Patchwork of Snapshots

What we 'see' is in fact a constantly changing field of information, which we continuously update and re-assemble into the 'big picture'. Our eyes dart about gathering data, retaining static information, while continuously scanning the scene and updating details that change within our fields-of-view.

The amount of image area we actually focus on at any given point in time is only about 0.5° of the total scene. The rest of the image is fuzzy and gets progressively so as you get towards the corners of the visual field. The details of what we see are the results of data collected by the light-gathering rods and cones, which line the rear, inner surface of the eye, with rods outnumbering cones by a ratio of about 10:1 (or about 120-million rods and about 7-million cones).

We only see color in the center portion of our field-of-view, which is where most all of the eye's color-sensitive cones are located. Cones are responsible for our daylight vision, and are dedicated to capturing red, green, or blue light. As daylight fades, the cones recede in activity and are supplanted by the rods, which are monochromatic. As a result, much of what we see at night is rendered in black and white.

Even in bright light, the edges of our field-of-view remain monochromatic. If you were to stare straight ahead while someone entered the corner of your field of vision wearing a red shirt, you'd remain clueless as to the color of the shirt was until your eye darted over to catch a fleeting glance of the shirt in question.

Light sensitivity is extremely acute in rods, which can detect light levels as low as a single neuron. As a point of reference, under average lighting conditions, our eyes recognize about 3000 neurons every second. And because the central area of our field of view is overwhelmingly populated with daylight-oriented cones (especially in the centrally-located fovea), we actually see more image detail off-center once the sun dips below the horizon.

This is most notable when stargazing on a clear night. If you allow your eyes to acclimate to the night sky and stare at a fixed point, you begin seeing clusters of faint stars off-center to the point you are focused on. Yet when you shift your eyes to any of these clusters, they (seemingly) vanish, and (seemingly) reappear in the area of the sky your eyes originally focused on.

Many animals, birds in particular, have far higher numbers of cones compared to us common folk, which enable them to spot small animals and other prey from great heights and distances. Conversely, nocturnal animals and creatures that hunt at night have higher numbers of rods to facilitate better night vision.

What is the Focal Length of the Human Eye?

Describing the focal length of our eyes requires a bit of background, since our vision encompasses and responds to a far greater set of dynamics compared to the cut-and-dry specs of that fancy zoom lens you've been dreaming about.

Human vision, as interpreted by the brain through 2 eyes, has a combined field-of-view of about 120-140°, sometimes a bit less, but seldom more. This means our eyes see the world much like a wide-field, panorama camera captures it on film, minus the distortions. But while the angle of view can be described as ultra-wide, the overall perspective and spatial relationships between objects within the image field are rendered as if taken with a 'normal' lens.

Contrary to the traditional industry standard of 50 - 55mm, the actual focal length of a normal lens is 43mm. (Note- Journalists and Leica owners will argue it's a 35mm lens… preferably - but-not-necessarily - the f/2 version).

After figuring in the wide-field factor and how it plays out in a 24x36mm field, you end up with – depending on numerous factors including ambient light, subject-to-eye distance, as well as the health and age of the individual – a focal length of about 22 to 24mm, with 22.3mm getting the majority vote as being closest to how we see.

Note- If you see claims of 17mm (or 16.7mm) as being the focal length of the human eye, this figure is based on an image projected outward from the inside of the eye. The incoming image has a focal-length equivalent to 22-24mm. Just as looking through the wrong end of binoculars makes the subject look further away instead of closer, so too the human eye. Hence the discrepancy.

For medium-format imaging, the fixed-mounted 38mm Biogon lens found on Hasselblad SuperWide-series cameras with its distortion-free, 90° corner-to-corner angle-of-view, would be the camera of choice for capturing the most accurate photographic renditions of 'how we see'.

So How Many Mega-pixels of Detail do Our Eyes Resolve?

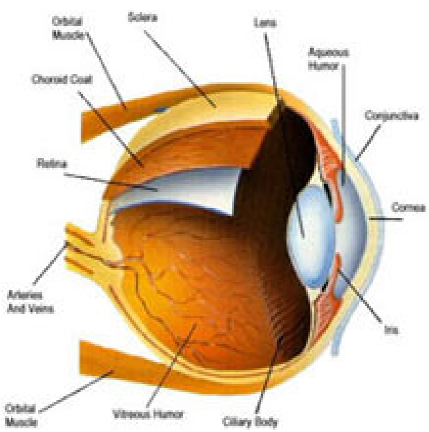
This is definitely the $64 question, mostly due to the fact what we see at any given moment is a composition of numerous bits of data gathered over multiple moments in time. Add to this equation age (our eyes weaken with time, and not at the same or constant rates) and the overall health of the individual.

One number that pops up commonly is 576MP, which is based on a scene with a 90° field-of-view, which is similar to what a 24mm lens on a full-frame 35mm camera takes in (and exactly like the Hasselblad SuperWide). This too is somewhat misleading, because unlike a photographic image, which depending on the f-stop used, can be sharp corner-to-corner, the human eye only resolves a small sliver of the total scene at any point in time. The fact that we resolve differing levels of color, contrast, and detail under different lighting conditions further clouds the numbers.

What DPI Setting Do You Actually Need to Produce a 'Sharp' Print?

According to one online estimate, a 74MP image file can produce a full-bleed 13x19" color print, which when viewed from a distance of about 20", resolves the maximum amount of detail that a normal human eye can resolve from a high-quality photographic print.

What's the ISO of the Human Eye?

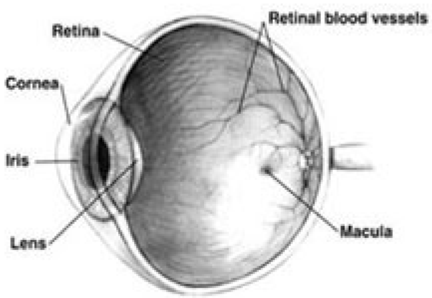


Here's another tricky one to nail down, mostly due the variables involved in coming up with an answer that sticks to the wall. The problem is that unlike film and digital sensors, the eye doesn't have a native, or base, ISO level. What the eye does have however, is an amazing ability to adjust to ambient light levels under the most extreme of lighting conditions, be they brightly-lit beach scenes or dimly-lit alleyways.

That said, the answer to the question is that under bright sunny skies the human eye has an effective ISO of about 1, and under low-light conditions an ISO of about 800. It's also worth mentioning the contrast range detectable by a typical human eye under brighter lighting conditions is in excess of 10,000 to 1, which blows away any camera/lens combination, film or digital.

And the F-Stop and Shutter Speed?

Based on the maximum diameter of the pupil of a fully dilated pupil, the maximum aperture of the human eye is about f/2.4, with other estimates placing it anywhere from f/2.1 through f/3.8. And once again, these figures decrease with age and/or health-related issues. Minimum aperture or how far our eyes can 'stop down' when romping in the snow or playing at the beach is about f/8.3 to f/11, again depending on all of the previously mentioned variables.



As for shutter speed, the human eye can easily detect flashes of light as short as 1/100th-second, and under controlled conditions shorter than 1/200th-second, depending on the ambient light and the by-now-familiar health/age-related issues.

Blind Spots

An oddity that exists within our fields of vision is a small blind spot that exists within each of our eyes. The rear inner lining of our eyes (the retina) is covered with gangs of nerve cells called photoreceptors. When light strikes these photoreceptors, it is turned into electrical impulses which in turn, are forwarded to the brain for further processing.

The point where these photoreceptors bundle together before heading off to our brains for batch-processing is known as the optic nerve head, which is devoid of photoreceptors. In a nutshell, it's a blind spot and a fairly large one at that.

In case you're wondering what this blind spot looks like (or doesn't look like), try this little experiment. While covering (or closing) your left eye, stare directly at the '+' below this text box using your right eye. At a certain point – roughly 12-or-so inches from the screen – the asterisk seemingly vanishes from view. If you reverse this process and watch the '+' with the right eye, the results repeat themselves.

+ *

How does this blind spot affect our vision? As it turns out, not much, since brain cells fill in the missing gaps of data.

(BTW, if you're concerned others around you will get weirded-out watching you moving your head back-and-forth in front of the computer screen, print the page and try it at home when nobody's looking)

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