Vision

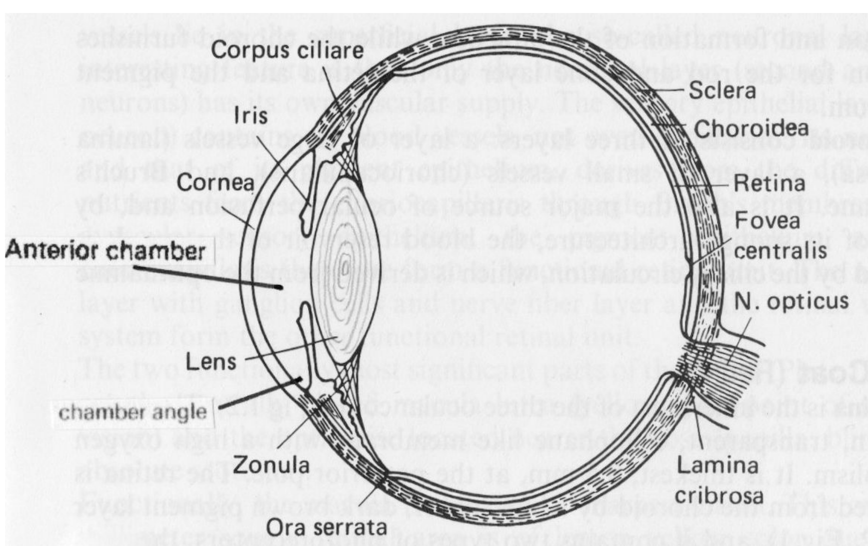
Our sense of sight

Darwinians and Creationists may argue about how our human eye came about, instead they should just take delight in their unique and most marvellous sense of sight, from the eye to the brain.

Having retired many years ago and having finished most of the projects that kept me busy for days, I have now much free time on my hands. So, on a sunny summer's day I am wont to sit in my lawn chair in our small garden behind our house and admire my ash tree. This tree, the trunk of which has a diameter of 40cm and whose top reaches about 30m into the sky, has so far been spared the destructive ravages of the emerald ash borer. It is a bit lopsided, just as I am since a bothersome dizziness hampers my walking. It grew up beside a large spruce tree whose sharp needles discouraged any branches from sprouting on this side. The spruce has since been cut after falling victim to the needle-dropping disease, thus exposing the ash tree's two mighty opposed branches like welcoming arms.

As I sit utterly relaxed and without worry in the shade of my ash tree, absorbed in the contemplation of its beauty, my thoughts wander. How do my eyes see this tree with its leaves rustling in the wind and the squirrels joyfully romping through its branches? How does my sense of sight work? I remember my article Dark Matter (*Micscape* Feb. 2024), and this is a sequel to it. We take too many things for granted and it behoves us to stop and reflect on the many gifts nature has endowed us with.

How many senses do we have? Five active ones: taste and smell, touch, hearing and sight. There are some more, such as balance and orientation and common sense. The latter, unfortunately, is all too often absent in some individuals. It is our sense of sight I am concerned with, which does not only comprise the eye but, most importantly, the brain, or more precisely, the visual cortex of our brain. Early on in human history wise men and women have puzzled about the eye. The first of whom we know to describe the human eye is Alcmaeon of Croton about 500 BC. Plato, in the 4th century BC ,was of the opinion that rays emanated (extramission) from the eye and are reflected back for us to see. His contemporary,



Section through the globe.

Aristotle, however, maintained that the eye received rays (intromission) for us to see. He was right as we now.know.

The eye is often compared to a camera. A camera needs a lens made of glass. The first glass was produced in Egypt and Mesopotamia around 1500 BC while the first useable "optical" lens appeared in Italy in the 13th century. As for the film, in 1725 the German professor of anatomy with an interest in chemistry, Johann Heinrich Schulze (I had to get that in!!!) discovered the light sensitivity of silver nitrate but did not realize the potential of his discovery, used it merely to amuse his friends. It took hundred years and several pioneers to develop workable cameras and film material and many books have been written on the subject.

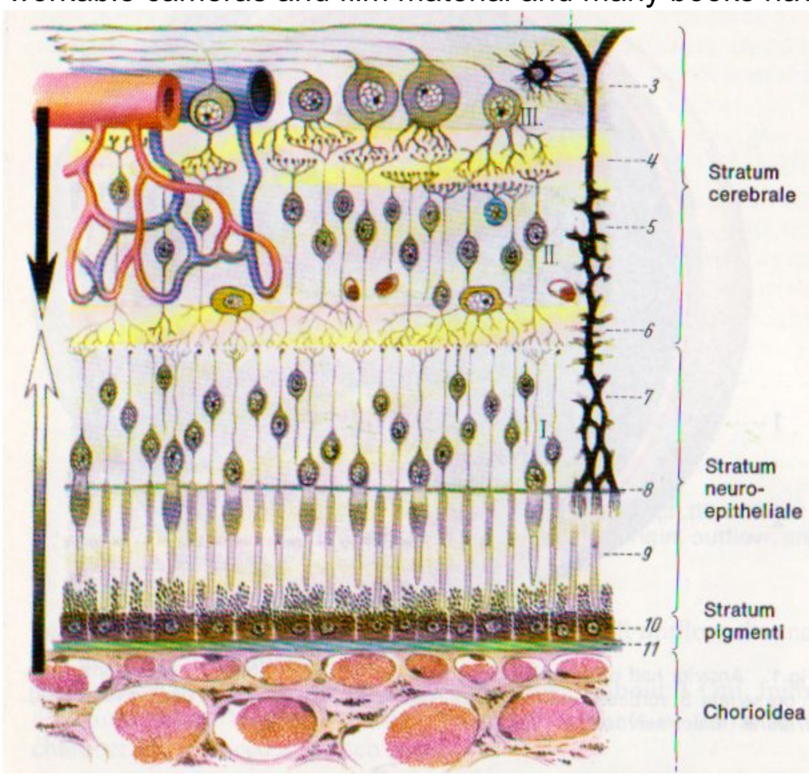


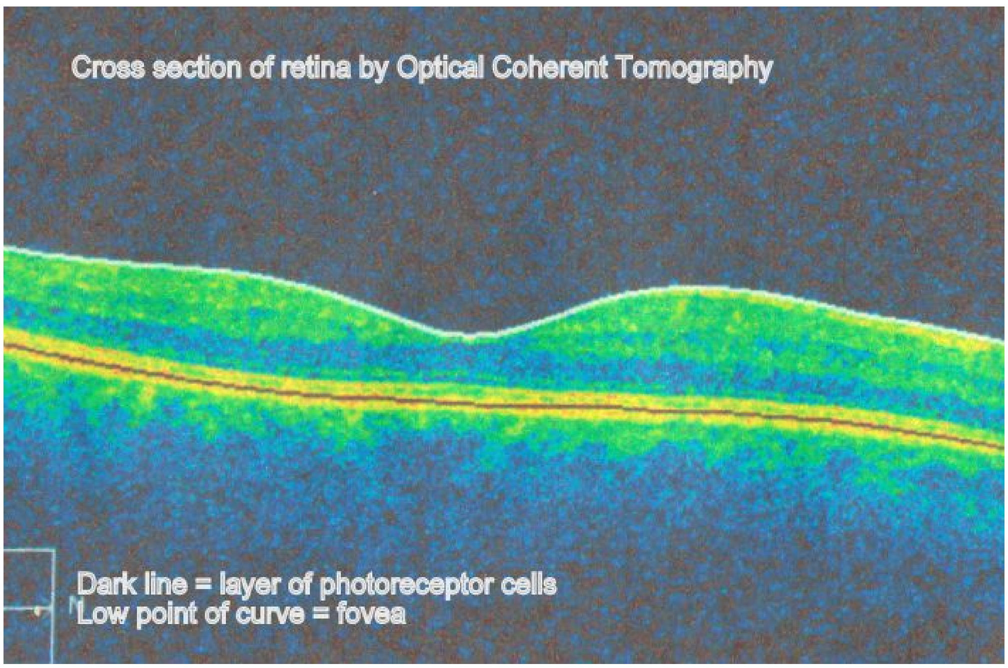
Fig 1. Section through the retina (from Thiel). I, first neuron (9–7). II, second neuron (6 and 5). III, third neuron (4 and 3).

1. Internal limiting membrane
2. Foot plate of a Müller cell
3. Nerve fiber and ganglion cell layer
4. Inner plexiform layer
5. Inner granular layer
6. Outer plexiform layer
7. Outer granular layer
8. External limiting membrane
9. Rods and cones
10. Pigment epithelium
11. Bruch's membrane

Arrows to the left of the drawing indicate the direction of flow of nutrients from the retinal vessels and from the choriocapillaris.

Looking at our eye as a camera, the objective consists of the cornea, the anterior chamber, filled with aqueous humour, and the lens, which does the actual focusing. In front of the lens is situated the iris which regulates the influx of light. The objective has a focal length of 17mm and angle of approximately 150º horizontally. Most of this angle covers our peripheral vision which helps us to negotiate safely in our environment, only about 10º are used by the fovea for our most acute vision.

In our eye the retina is the equivalent of the camera's film. Just as the photographic plate has to be “developed” after exposure to light, so the latent image on the retina has to be processed by our brain for us to “see”.The retina has several layers, one of which contains approximately 130 million photoreceptors (which in our digital age we could call “pixels”): 120 million of which are rods, responsible for night and peripheral vision, and 6 million cones, which are sensitive to colour (some for red, others for green or blue) and are densely concentrated in the fovea, the 1.5 - 1.7mm diameter focal point of our most acute vision. These cones are 0,004mm separate and their distance from each other defines our “resolution” or acuity. Digitally speaking, our eye has 576MP (megapixels).

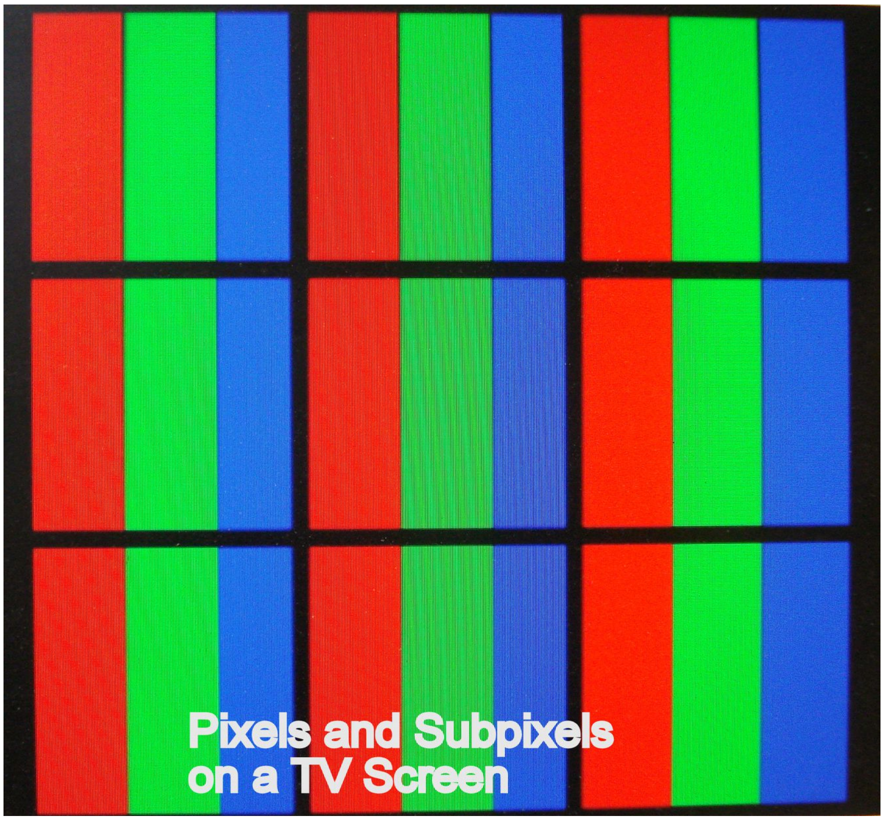


When stimulated by light, the photo-receptors produce a chemical reaction that sends a signal via the optical nerve to the visual cortex. This is a continuous process as long as our eyes are “open” and we are awake. It is obvious that this represents a huge amount of data every second, minute, hour or day which our brain has to process. But not only that, we have two eyes, hence the sum of data is doubled to create our stereoscopic vision.

Now it gets a bit technical but I shall try to make it simple. When a photosensitive cell is hit by photons, it takes a certain time to react. This can range from 4ms (cones) to 200ms (rods). After emitting its signal it requires again a certain time to refresh to be ready for the next cycle, thus determining the modulation or frequency of the signals that are conveyed to the brain. This “critical flicker frequency” ranges from 15 Hz (rods) to 60 - 90Hz (cones) so that we can see “fluid” motion without any flicker. The flicker frequency depends among others on the wavelength and intensity of the light and the location of the photoreceptors on the retina.

These modulated signals reach the visual cortex via the optical nerve to be processed and presented instantaneously to our mind as a picture and simultaneously stored in our short-term or long-term memory from which the information can be recalled = pattern recognition. This is a highly condensed layman's description of the process of human vision. More details can be gleaned from Wikipedia/Vision_Science or /Critical Flicker Frequency.
Keep this in mind when I now proceed to the 21st century and our digital image processing.

In order to process an image digitally it has to be broken down into tiny image points, pixels. Each of these has a value that can be processed. To create such data , the image on the photosensitive sensor of the video camera is scanned row by row sequentially. For example, a professional 8K video camera has a sensor with 7680 pixels in every horizontal row (line) in 4320 vertical rows (lines) i.e. a total of 33,177,600 pixels (= 33.2MP). For a moving picture not to flicker, we require a minimum of 24 “frames” per second. In reality the scanning frequency can be up to 120 Hz, That means that the 33 million pixels have to be scanned and stimulated 120 times per second, a huge amount of data. And as each pixel has to react separately to red, green, and blue, as well as to a certain level of luminance (brightness), these data must be multiplied accordingly.



After being processed these data are sent to a video monitor or TV set for us to watch. The TV set has a similar amount of pixels also arranged in horizontal and vertical lines (See picture above, highly magnified). For example, a 49” TV set has 2 million pixels, each with three subpixels for red, green and blue. To recreate the image, these pixels have to be stimulated sequentially, again for example at 120Hz to avoid flicker. If a pixel is not stimulated, it remains black, if all three subpixels are stimulated, it appears white, stimulation of any or all subpixels results in whatever colour is desired. The luminance, in turn, can reach from almost dark to maximum brightness.
How our ingenious electronic engineers have achieved this marvel of technology, is a mystery

to me. I always imagined tiny wires going to each pixel for its control ! It is impossible to explain the wonder of our sense of sight and the digital technology of vision in a short article, particularly by a layman. So forgive me if I got some things wrong.

Having gained some insight into and being thoroughly impressed by the miracle and complexity of our sense of sight and the modern digital imaging systems it is just plain overwhelming trying to fathom the wonderful processes in our 1.5kg organic brain. The immense quantity of signals from our two eyes reaching the visual cortex of our brain continuously zoom through millions and millions of neurons and synapses instantaneously and untiringly to create in our mind the images we see. Much energy is consumed during these processes, hence the ample blood supply our brain demands. And all this is done without any overt effort on our part, although overstimulation may result in a headache.

What an unbelievably wonderful imaging system do we carry in our head and don't appreciate it until we either suddenly require eyeglasses, develop a cataract or macular degeneration. So, come summer I shall again be totally lazy, lounge in my lawn chair, dream and be thankful thankful that I am able to delight in the soothing green of my ash tree.

Credits: As all my books were published BDE - Before the Digital Era - I relied to a large extent on Wikipedia for most of the technical information. The (horizontal) cross section of the eye and the schematic of the retina I took from Fritz Hollwich “Ophthalmology” A short textbook,, 1979, the OCT image (of my right eye) was obtained from Dr. J.A. Martin, Hamilton, ON.(with Zeiss OCT Cirrus 5000, 2020) Further information on the anatomy of the eye I gleaned from Handbook of Ophthalmic Optics, Dr, Helmut Goersch, publ. by Carl Zeiss 1991.

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