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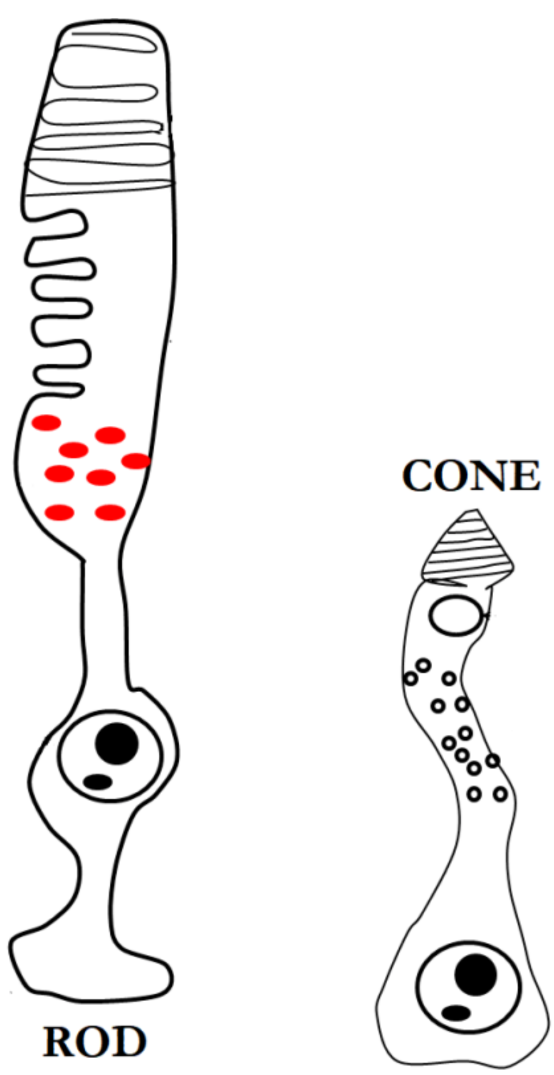
December Article Summary:

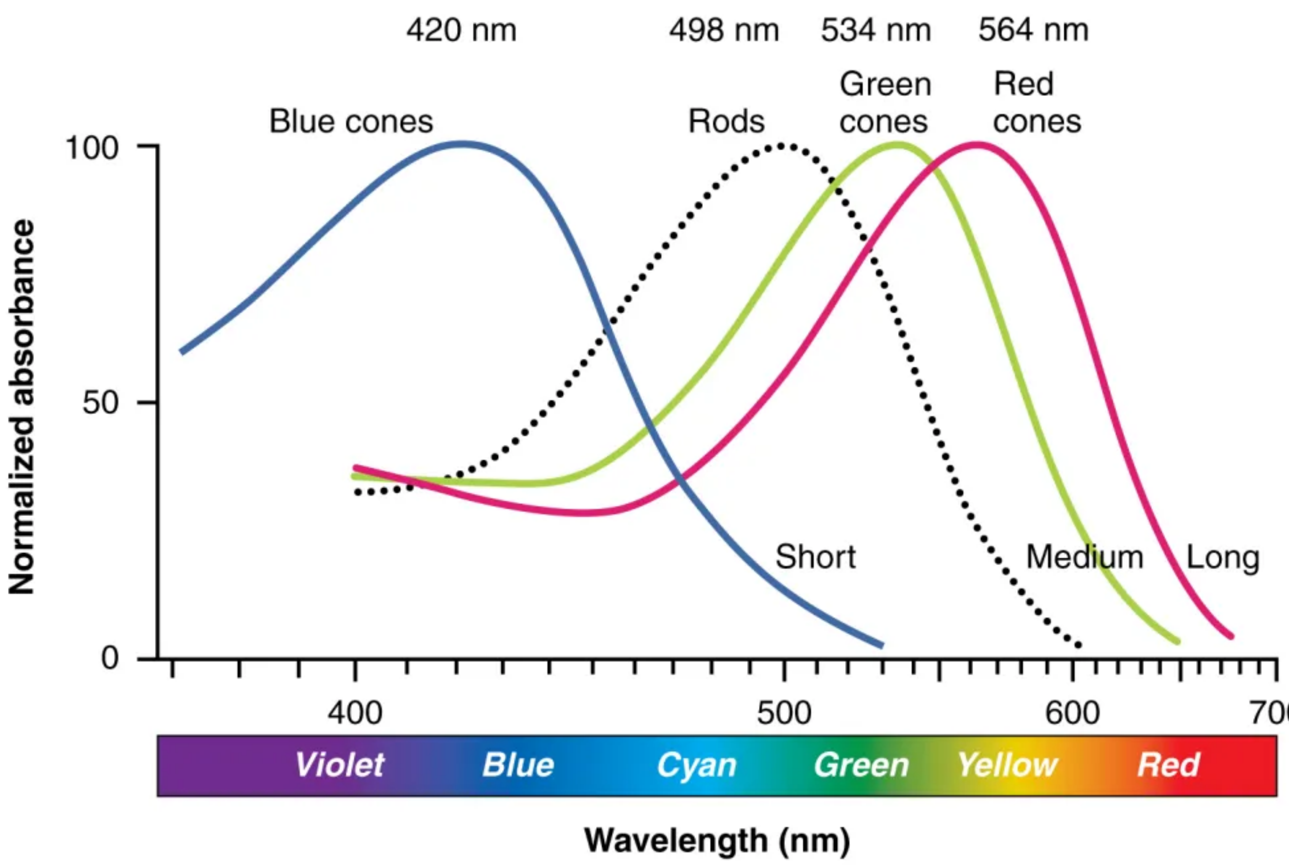
Last month, we followed the path of light as it raced from the sun towards the earth. The light hit objects and reflected into the eye, passing through the eye's lens and cornea. The lens and cornea determined how much light could enter the eye, we learned, based on the internal emotional and physical state of the person at that moment.

Today, we sit at the back of the eye and watch as the light hits oddly shaped structures called rods and cones. As the light hits these towers and stumps, the photopigments stored within change shape to release a signal that determines the brightness and color of the viewed object.



Rods and cones release a signal to light that helps the brain interpret the light's brightness and color. *Retrieved from WikiMedia Commons.*

This article will focus on cones, which primarily provide color vision. Most humans are trichromats, meaning they carry three “flavors” of cones: a short-wavelength cone for blue colors, a medium-wavelength cone for green colors, and a long-wavelength cone for red colors. All other colors arise from combinations of activity from these three cones.



Most humans have three types of cones – blue, green, and red. A select few have a fourth type that reacts to light between green and red. *Retrieved from WikiMedia Commons.*

More than one in ten women, however, carry an extra type of cone. The extra cone is typically a slightly altered version of the long-wavelength cone. Since the extra cone is located on the X chromosome, only people with two X chromosomes can be potential tetrachromats, as they are called. After more than a decade of research, the question of how this extra cone affects the vision of tetrachromats remains a mystery.

The study was small and simple. One by one, six women sat in front of a computer. A researcher asked them to watch the monitor and note whether the object on the screen rotated towards the left or the right. Unbeknownst to the women, the researchers used a bit of animated movie magic – employing a sequence of different still images to create the illusion of motion – to figure out whether any of the women had superhuman vision

In the task, a screen toggled between two images of a ring with different pairs of alternating colors along the border. If an individual perceived one color as brighter than the other, the object would appear to rotate consistently either to the right or the left. If an individual perceived the two objects with equal brightness, the motion would become unclear and someone would experience the object as turning to the left or right with equal frequency.

The test, called the "minimum motion" task, can be further explored here[2,3].

Of the six women participating, four carried the extra type of cone that can grant the ability to see more colors than average. Yet three out of those women failed to distinguish colors beyond that of typical human variation, confirming previous research that shows the extra cone does not guarantee superior color vision.

The results were different for the fourth woman, a California-based artist by the name of Concetta Antico. She showed an ability to detect differences in color and brightness that out-rivaled any of her peers. Antico became famous for her colorful paintings and tetrachromat status back in 2014[4], but the present study supported Antico's status as a functional tetrachromat.

Concetta Antico, a confirmed and functional tetrachromat artist. *Retrieved from WikiMedia Commons.*

One of the impressive aspects of Antico's art is her ability to portray color in low-light conditions like dusk or sunrise. In the present study, Antico exceled at distinguishing red colors and low lightintensity. Researchers from the present study believe that her extra cone may pick up light that would be difficult for most observers to detect. (Image: "Shiney Moon, La Jolla"- by Concetta Antico)

What is special about Concetta Antico, and why did she demonstrate a superior sense of vision while the other potential tetrachromats did not? There are many possibilities, but I explore four here.

First, the quality of the extra color cone matters. A year prior to the present study, a wonderful science blogger named Sofia Deleniv proposed that the fourth cone that a woman carries must differ enough from the other three cones to allow one to see extra colors[5]. I recommend anyone with an interest in tetrachromacy to read her article here.

Second, it is possible that the brain must adapt to process the extra color information. A long-standing debate in the field of tetrachromat research is whether the brain can adapt to handle the extra color information it receives from the fourth cone. Studies show that the brain is capable of remodeling and change, especially early in life, but the limits of its plasticity are not fully understood. One theory argues that potential tetrachromats need certain early-childhood events or training to unlock their ability to see additional colors. Dr. Kimberly Jameson, the author of the present study, argues for this interpretation. She claims that Antico's status as an artist may have given her a lifetime of training that permitted her to interpret additional visual cues. Another artist in the study, a trichromat, was not able to see color with any difference. (Image: "Magic in the Moonlight, Mission Hills" – by Concetta Antico)

A third possibility lies in the nature of the X chromosome. Many women have two X chromosomes, while many men have one. To make the genetic information in cells equal between the sexes, cells "turn off" one X chromosome if two are present. The silenced chromosome gets tightly coiled until its genes are inaccessible to the cell's molecular machinery, creating a clump that researchers can see under a microscope.

The arrow points to a hyper-coiled and non-functional X chromosome inside a cell. Stanley M Gartler, Kartik R Varadarajan, Ping Luo, Theresa K Canfield, Jeff Traynor, Uta Francke and R Scott Hansen, CC BY 2.0, via Wikimedia Commons

Most potential tetrachromats carry two versions of the long-wavelength cone, with one version on each X chromosome. The inactivation of X chromosomes in different cells can produce a wide variety in the relative numbers of the two cones.

The concept of X-inactivation is tricky, so here's a visual example. Below are four "cells" in a person who carries two versions of the long-wavelength cone (one sensitive to red on X chromosome #1 and one sensitive to yellow on X chromosome #2). Each cell picks one X chromosome to turn off at random. To become a functional tetrachromat, a certain number of each cone might be necessary, or a certain number in a certain region of the retina; those with too few of one cone and too much of another could end up with "normal" color vision. Further, X-inactivation is not always random, and one X chromosome is sometimes favored over the other[6].

The final possibility is the least enticing, but one that must be addressed. The present study looked at six people, and only four were potential tetrachromats. A larger study could reveal that the extra cone adds nothing at all to color vision, and individuals like Concetta Antico just have an extreme variation of normal sight. After all, color vision does differ to some extent in all individuals, and studies with small numbers of people produce unreliable results.

Whether a lucky break or an unlocked potential, functional tetrachromacy remains mystifying. More research must be done to tease apart each of the individual theories, but there is clearly much left to learn from the women with kaleidoscope eyes.

I'll finish with a fun fact and a final thought: If the fourth type of cone carried by tetrachromats impresses you, the humble mantis shrimp carries sixteen distinct types of color cones. It's no exaggeration to say that their vision is, to our minds, unimaginable.

The Mantis Shrimp. *Retrieved from WikiMedia Commons.*

Stop by next month to learn about why the colors we interpret are not actually the colors we see, and how this affects the work of artists and conservators.

Citations:

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4. Robson, D. "Future – The women with superhuman vision." BBC, BBC, 5 Sept. 2014, http://www.bbc.com/future/story/20140905-the-women-with-super-human-vision.
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