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How to make scientific figures accessible to readers with color-blindness

by Emily Summerbell

Proper data visualization is critical for presenting your scientific work in an accessible way. It's important that people can easily and quickly understand your data. A sloppy scatter-plot or unconvincing immunofluorescence image can lead others to misinterpret or even mistrust your data. Scientists often fail to design figures from the perspective of our readers, particularly readers with disabilities. Although there are many important aspects to designing accessible figures, I want to talk specifically about making figures accessible for people with the most common visual disability: color-blindness.

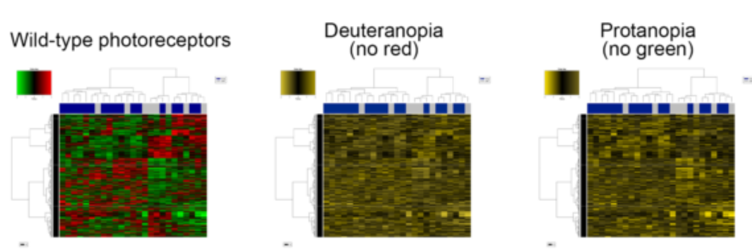
Why you should care about color-blindness

Color-blindness affects a large portion of the population. As many as 8% of males and 0.5% of females have some form of color-blindness, the most common being difficulty in perceiving the difference between the colors red and green. This means that potentially **one out of 12 males and one out of 200 females** who read your paper or walk past your poster can't easily read your figures with certain color combinations.

The genetics behind inherited color blindness are quite interesting, but let's skip to some practical steps for making your figures more readable. It's also important to note that color-blindness is different for every person; many possible inherited mutations can change how the eye perceives and interprets different colors. This means that what works to make a figure readable by one person may not work for everyone.

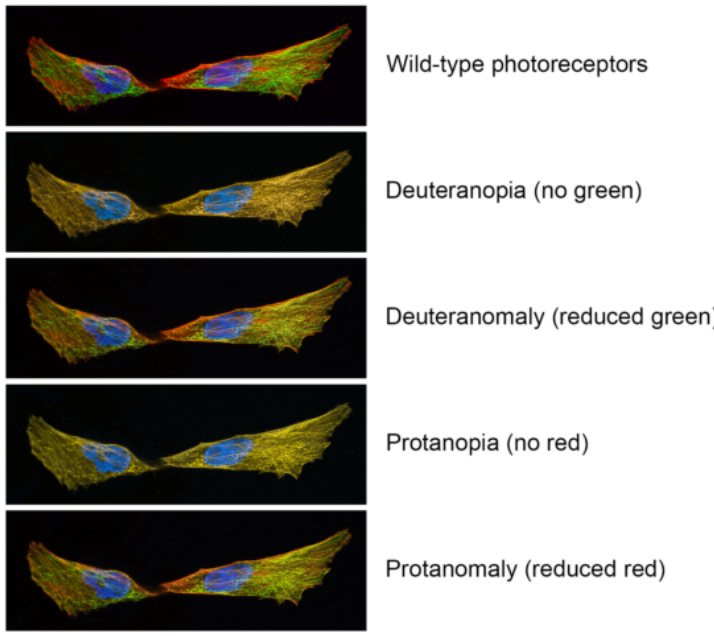
It's time to ditch red and green forever

The red/green color combination is classic in science, most commonly used in heatmaps and fluorescence images. For people with normally-functioning photoreceptors, red and green provide good contrast. However, if a person has a mutation in their red or green cone cells, distinguishing these two colors becomes much more challenging. For example, take a look at what a red/green heatmap might look like to people without functioning red or green cone cells:



Three heatmaps of z-score normalized gene expression data. The first heatmap is in a green-black-red color scale and labeled "Wild-type photoreceptors." The coloring and dendrograms show two main clusters of samples in columns and two main clusters of genes in rows. The second heatmap has been filtered to simulate how it would appear to a person lacking red cone cells (i.e., deuteranopia), and the third heatmap has been filtered to simulate how it would appear to a person lacking green cone cells (i.e., protanopia). These two heatmaps appear in shades of yellow and black, with the negative and positive values indistinguishable from each other.

Fluorescence images are just as challenging. This is what a red/green color merge might look like for a person with different variations of red/green color blindness:

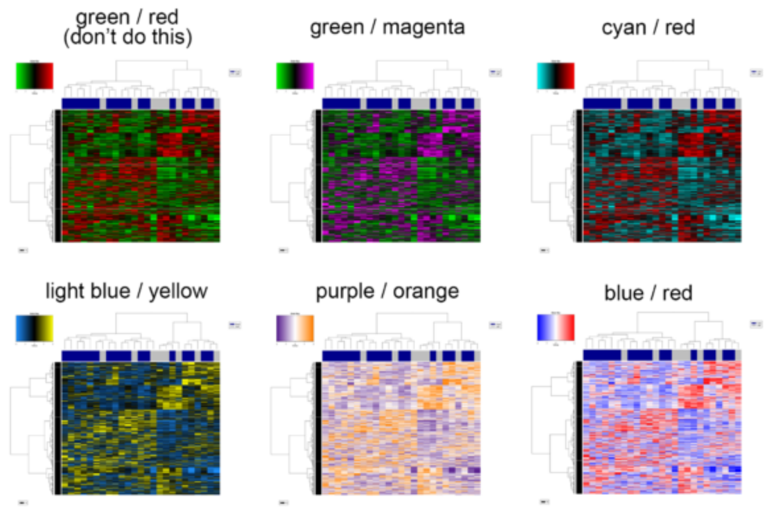


Five versions of an immunofluorescence image of two cancer cells. In the top image, labeled “Wild-type photoreceptors,” actin is labeled in red, tubulin is labeled in green, and DNA stained by DAPI is in blue. The four images below filter the original image to simulate four variations of red/green color-blindness: deuteranopia (no green cones), deuteranomaly (reduced function of green cones), protanopia (no red cones), and protanomaly (reduced function of red cones).

There’s a very simple solution to the problem of unreadable figures: **stop using the red/green color combination.** Yes, it’s that easy! In fact, many journals now strongly encourage authors to use other color combinations in their figures. Not only will it be easier for everyone to interpret, but new color combinations are also just as (if not more) visually appealing as red/greed. Some alternative two-tone color combinations include green/magenta, yellow/blue, and red/cyan. Even better, only use multiple colors when necessary. You can convey most data just as well using black/white, greyscale, or a monochromatic color scale, so don’t use two colors solely to make your data “pretty. ”.

How to make a better heatmap

When choosing colors for heatmaps that show low values, a median, and high values (such as z-score normalized gene expression), it’s best to pick two complementary colors for the ends of the scale and either white or black for the middle. Historically, warm colors represent “up” and cool colors represent “down,” but that’s not a steadfast rule. If you use black for the middle color, choose two lighter colors for the ends of the spectrum; if you use white for the middle color, choose two darker colors for the ends. For example, here are some more accessible ways to color-code a heatmap:



Six different ways to color-code a gene expression heatmap. The first heatmap is in a green-black-red color scale and labeled "don't do this." The next five heatmaps are representing the same data but in color combinations that are more easily visualized by people with red/green color-blindness. The color scales on these five heatmaps are green-black-magenta, cyan-black-red, light blue-black-yellow, purple-white-orange, and blue-white-red.

Similar color rules should be used when [designing maps, density plots, or other kinds of data that rely on a gradient of color](). Avoid the use of rainbow spectrums and instead, use scales such as green/purple or a modified rainbow with no green. Also, include different shapes, lines, or symbols to represent different sample types when possible to make the differences stand out even without considering color.

How to present more accessible microscopy images

Similar color ideas apply to microscopy, but it gets a bit trickier to find suitable color combinations when there are three or four colors in one image. A better three-color combination would be magenta/yellow/cyan. For four colors, try magenta/yellow/green/blue. In addition, it is always best practice to show greyscale images for every individual channel next to a merged image. In fact, the human eye is far better at detecting changes in greyscale than in color. This way, there's no ambiguity as to where each signal is and how strong it is. For example, here's the same immunofluorescence image seen above but with separated channels and better colors in the merged image: