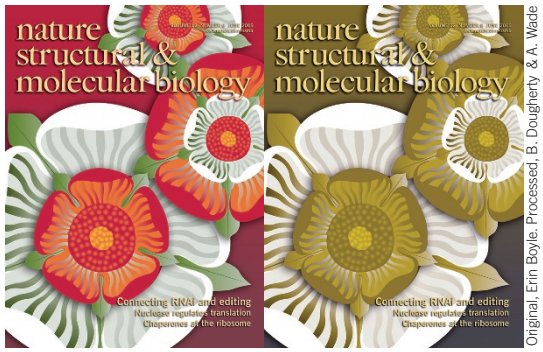
nature structural & molecular biology

Seeing science in color

Around 7%–10% of men have some form of what is commonly called red-green color blindness. New style specifications at *Nature Structural & Molecular Biology* aim to enable all readers to see the full spectrum of data in images.



Original, Erin Boyle. Processed, B. Dougherty & A. Wade

In 1794, John Dalton, the father of atomic theory, presented his first scientific paper to the Manchester Literary and Philosophical Society. Rather than discussing fundamental particles, he described how he and his brother saw the world. Dalton noted that he perceived red wax as the same color as a laurel leaf. Such examples of the unusual nature of his perception led him to present one of the earliest scientific papers addressing color blindness. Being interested in optics, Dalton hypothesized that his different perception of color was due to the fluid within his eye being blue. With admirable commitment to the experimental pursuit of this idea, he asked that his eyeball be dissected posthumously to check the theory. In fact, his vitreous humor turned out to be fairly normal in color for a man of his years. However, in 1995, the preservation of Dalton's eye tissue allowed Mollon and colleagues to diagnose him with a specific form of color blindness called deuteranopia (*Science* **267**, 984–988, 1995).

This ability to diagnose Dalton's condition almost 200 years later, as well as the shared condition of Dalton and his brother, point toward the genetic basis of some forms of color blindness. Indeed, red-green color blindness is now a favorite topic of genetics courses, since it is a classic sex-linked trait as well as a good example of what can result from recombination error. Human color vision is based on opsins that detect three wavelengths of light. The red and green opsins are highly related at the sequence level and the genes are closely located on the X chromosome. Unequal recombination can thus relatively easily remove the green (deuteranopia) or red (protanopia) opsin gene. Lack of complementation in XY progeny leads to less ability to differentiate the red and green portions of the spectrum (though color blindness may allow more acute differentiation of certain shades, such as khakis).

In the right image, which simulates deuteranopia, red and green are indistinguishable (image processed at http://www.vischeck.com). This cover image, which might have greeted a deuteranope picking up our June 2005 issue, raises the problem of how differential color perception affects the way that people view and indeed do science. Although some potential problems, such as perception of pH papers and dyes, are increasingly obsolete with the widespread use of pH meters, other everyday lab tasks remain difficult for the color-blind. Joseph Ross (Fred Hutchinson Cancer Research Center, Seattle) points out that "some agarose and acrylamide gel ladders use tracking dyes that can be hard to see." Even more of a minefield, however, are issues arising in scientific presentations. A well-attended talk could contain 250 audience members, and because up to 10% of men have some form of red-green color blindness, it is possible that ten people in that audience find some slides difficult to see. One of the biggest culprits can be that fundamental presentation tool, the laser pointer. Most sticks have now been replaced with these devices, and the cheapest laser pointers are red. However, these are very difficult for people with red-green color blindness to pick out. Here, Ross notes that green laser pointers are available, and as these are brighter than their red cousins, they are actually easier for all audience members to see, despite their color.

Apply the above incidence of red-green color blindness to the legions of loyal *NSMB* readers, and the number of people who might have difficulty perceiving all aspects of the data in a paper becomes troubling. Red and green are often used to illustrate differences in data, but their use may cause problems in discerning overlap, as well as confusion about which data set labels refer to. Immunofluorescence data are the most obvious example of red and green contrasts, a logical choice given the emission spectra of the brightest and most easily distinguishable fluorophores. A similar argument underlies the use of red and green for microarray and probing data. However, most digital cameras actually sense fluorescence intensity in grayscale, with color applied later in the process. This color choice is also common in graphical representations of data — for example, in 'heat maps' used to represent variables by color in two-dimensional data, such as microarray and clustering data — as well as in sequence alignments and graphs. Structural data are more complex: here, an array of colors may be needed to highlight different residues or elements of a structure. However, convention in structural depiction also calls for red and green, with red traditionally used to highlight acidic regions (perhaps indicating the long historical reach of certain pH dyes) and green indicating hydrophobic areas. Though red and green are easily distinguishable to most people and thus seem a reasonable choice, their use sometimes seems more linked to historical precedent than anything else.

The revised *NSMB* style guide asks that contrasts of red and green be avoided in graphs, models and schematics. For primary data, color changes are optional, but we will encourage authors to at least check the visibility of and, if they choose, automatically correct coloring using the VisCheck and Daltonize algorithms at http://www.vischeck.com. It may seem like we are asking a lot to accommodate what is, after all, a small portion of our readership. As time goes on, however, we hope that new color conventions that are easy for all to perceive will fall into place — something that John Dalton himself might well have appreciated. ■