In the Words of a Neurobiologist

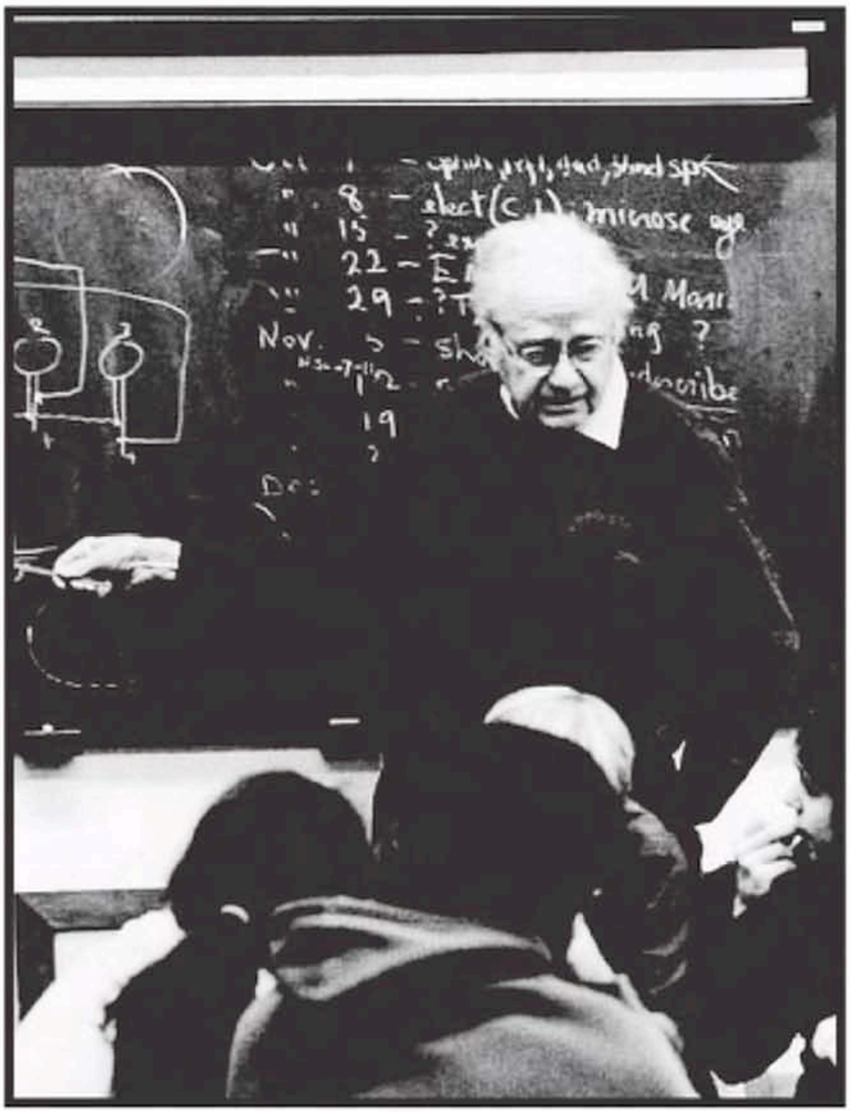
"Is it possible that when I look at an object that appears to me green, someone else sees it as red?"

A reflection by Nobel Laureate Dr. David H. Hubel

One of the questions concerning the mind that we hear very often posed by philosophers and undergraduate students alike runs as follows: "Is it possible that when I look at an object that appears to me green, someone else sees it as red?" In such discussions, philosophers tend to use the word "qualia", a term whose meaning has always escaped me, but is defined as what a mental state feels like to any given person, such as hearing a Beethoven bagatelle or sampling the scent of tea leaves. The perception of red versus green seems a good example of an intriguing question that today neurobiology can address easily and completely.

Different wavelengths of light are handled very differently by our nervous system. Our retinas contain two main types of light-sensitive cells called rods and cones. Of the two, rods are far more sensitive to light and can work at levels of light intensity that are too low to stimulate cones, such as in moonlight when the world appears in black and white. In daylight, rods do not contribute to our vision: they are worked so hard that they are insensitive to differences in brightness. Rods also cannot contribute to our color vision because they are all of one type. Cones, our photoreceptors responsible for color, are present throughout our retinas, but are especially close-spaced in the center part, the fovea, enabling particularly precise vision.

Cones are of three types that differ from one another in the wavelengths of light to which they respond best. There are long, middle, and short-wavelength sensitive cones, or loosely



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Nobel Laureate and Harvard Medical School Professor David Hunter Hubel speaking, there are cones maximally sensitive to red light, green light, and blue light. These three types of cones differ from each other in several ways. Red and green cones have identical shapes, but contain light-sensitive pigments that vary just enough to account for their sensitivities to different wavelengths. The blue-sensitive cones are far fewer in number compared to red and green cones, and are also different in size and shape. Chemically, the light-sensitive pigments that blue cones contain are also quite different from the pigments in red or green ones. In recent years, blue cones have even been shown to be absent from the center half-millimeter of the retina—which comes as a surprise given that we think we see blue everywhere we look.

"If we were to trade yellow for green... would yellow still be complementary to blue?"

The connections that these three cone types make with subsequent cells in the retina (called horizontal cells, bipolar cells, amacrine cells, and ganglion cells) are very different and rather complex. For some "subsequent" cells, the red and green cones work in parallel: those excited by red cones are also excited by green cones; those inhibited by red cones are inhibited by green. So white light, containing long, middle, and short wavelength light, exerts a powerful influence on these subsequent cells. But for other subsequent cells, the red and green cones work in opposition: if red excites, green inhibits, or the reverse. White light, therefore, leaves them unaffected as excitation cancels out inhibition. The blue cones, on the other hand, connect with still another class of "subsequent" cells, for which the red and green cones together work in parallel, and in opposition to the blue cones. Consequently these "subsequent" cells are turned on by blue and turned off by red or green (or vice-versa), and are again unaffected by white light. Finally, a third class of cells receive parallel inputs from the three cone types and respond well to white light, either by being inhibited or excited.

The main point here is that the three types of cones are hooked up differently—but in ways that allow us to understand color vision to a far more profound degree than was previously possible. The equipment in the retina and further centrally in the brain that we are using to see colors differs markedly from color to color. In the same way, our sensory equipment differs for the perception of different frequencies of sound or for the detection of hot and cold. So asking if what you see as red is what I see as green is like asking if a note on the piano that you hear as high (hitting a key at the right end of the keyboard) is like what I hear on hitting a key at the low (left) end—or if what feels cold to you feels hot to me. Try this with a kettle of boiling water. It reminds one of Johnson, James Boswell's protagonist, who, when asked if a stone was real, answered that one can find out by kicking it. The original question, then, seems simple as soon as one knows just a little biology. Kicking the stone corresponds to learning about cones and their connections; the original color question on qualia provokes intriguing speculations, but only until the science is known

Without wanting to beat the subject into the ground, a few more things can be said about the trading places of colors. If we were to trade yellow for green, for example, would yellow still be complementary to blue, or would green still be complementary to red (in the sense that the two, when added together, give white)? Red resembles orange and blue resembles green in ways that red does not resemble green or blue yellow. Ewald Hering pointed this out a century ago. We can speak of a reddish yellow but not of a reddish green. The physiological reasons for these facts are now well understood. If someone were to see colors in a very different way, it could not be just in any old way: the new way would have to be compatible with the same rules. Then, perhaps, the new way would be identical to the old, giving further food for philosophical thought.

Theoretically, it does seem conceivable that if we could suddenly get inside someone else's self we might find that his (or her) green was like our red, but knowing a few basic things about color vision makes it extremely unlikely. It also seems that a question posed this way is always going to be hard to answer considering the awkwardness of trading places with someone else. Although curious minds have pondered this question for centuries, it seems as though the neurobiological answer will have to suffice.

Of course the word "green" does not necessarily mean the same thing to all people. This has to do with language, expressions, and so on and not with sensory apparatus. "Green" can mean inexperienced, being vegetarian, jealous, or even adhering to a liberal political party. "Green" has some of the ambiguity and magic of words like "sky" and "mind." And while in no way wanting to deprive ourselves of the mystery and charm of these words, we had better make room in our thoughts for the science as we analyze and tear apart their meaning. To be sure, someone a hundred years ago could have asked, reasonably, such questions about red and green, but today, even as recently as the last few decades, we have managed to resolve the quandary unequivocally, or so we hope. It seems just as possible that as our knowledge about the brain continues to increase, other questions we pose about the "mind," such as consciousness, free will, and the rest, may similarly recede from scientific discourse, while nonetheless maintaining their usefulness for other, still not uninteresting, purposes.