Why do colours look the way they do?

(revised, June 2011)

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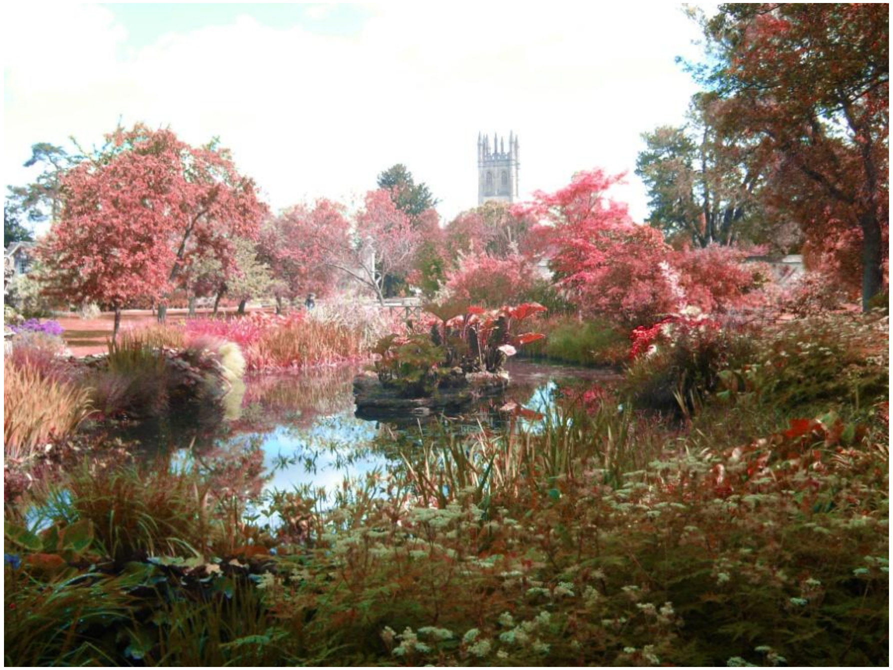
This **PowerPoint** presentation is designed as an accompaniment to my paper, 'Why Do Colours Look the Way They Do?', **Philosophy, volume 86 (2011), issue 03, pp. 405-424**.

It contains colour illustrations of certain key ideas discussed there, followed by several digitally edited photographs which depict various kinds of inverted spectrum.

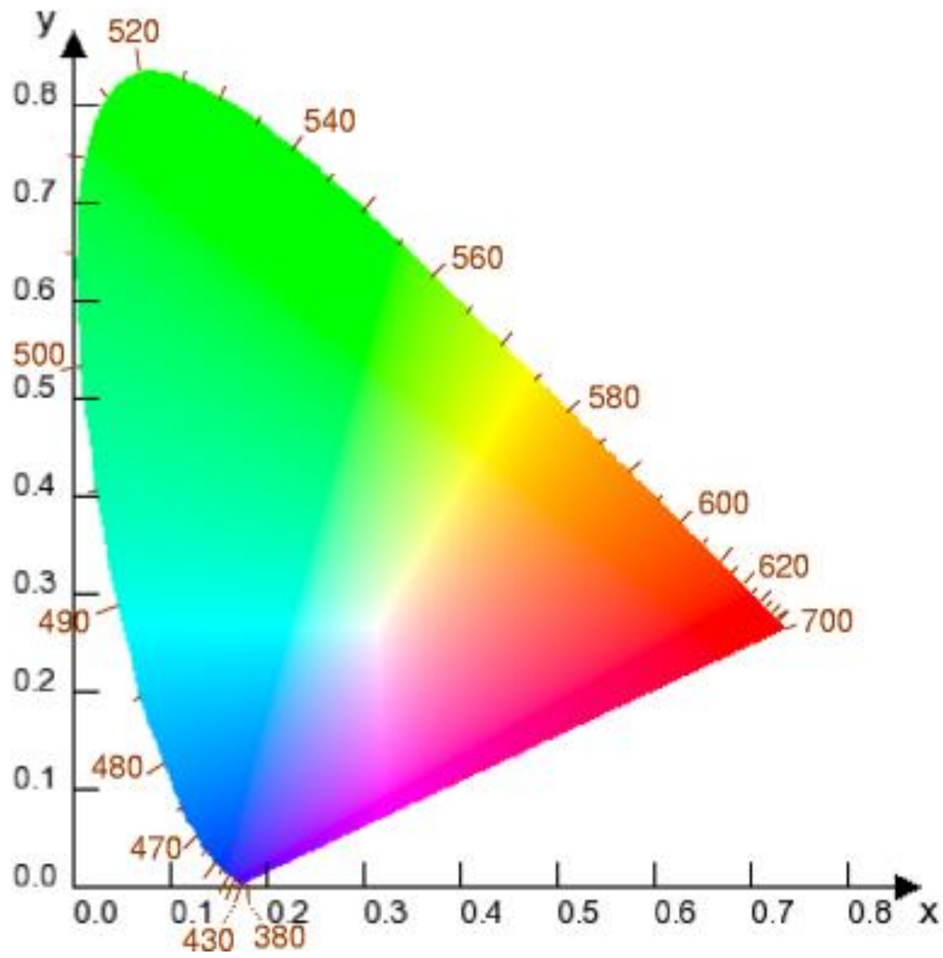


Botanic Garden, Oxford, as seldom seen (?)

Colour-hue and physics

- The visible spectrum is located (roughly) between 400nm (violet) and 700nm (red). (1nm = 10^{-9}m)

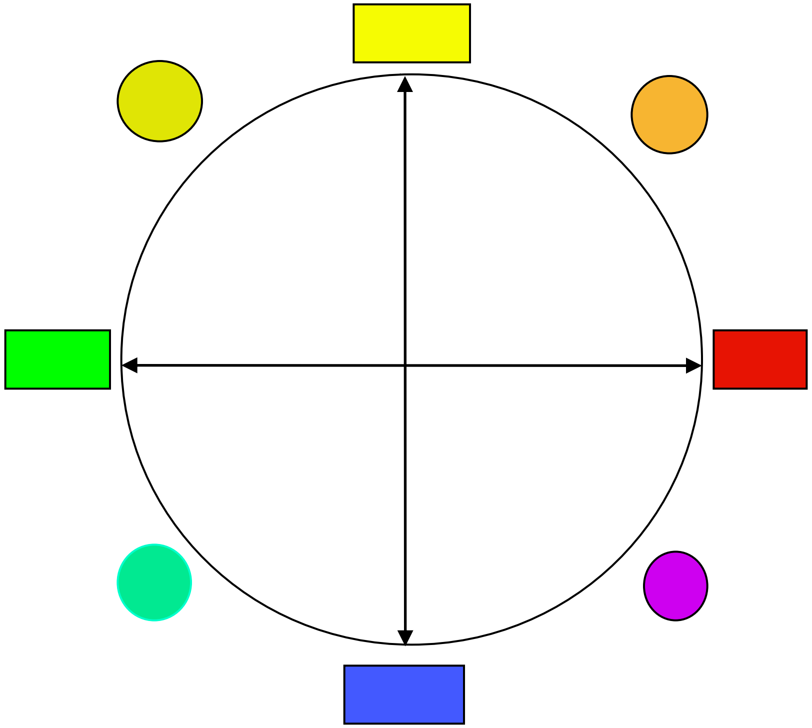
- The perceived hue of an object depends primarily on the dominant wavelength of the reflected light. (But most purples are non-spectral, and can only be produced by mixture.)



The CIE 1931 colour space chromaticity diagram

The Hering colour circle

(**Ewald Hering,** 1834–1918. Austrian physiologist and founder of modern colour vision science.)



•There are four ‘unique hues’ - **yellow**, **red**, **blue**, and **green**. These hues look essentially unmixed.

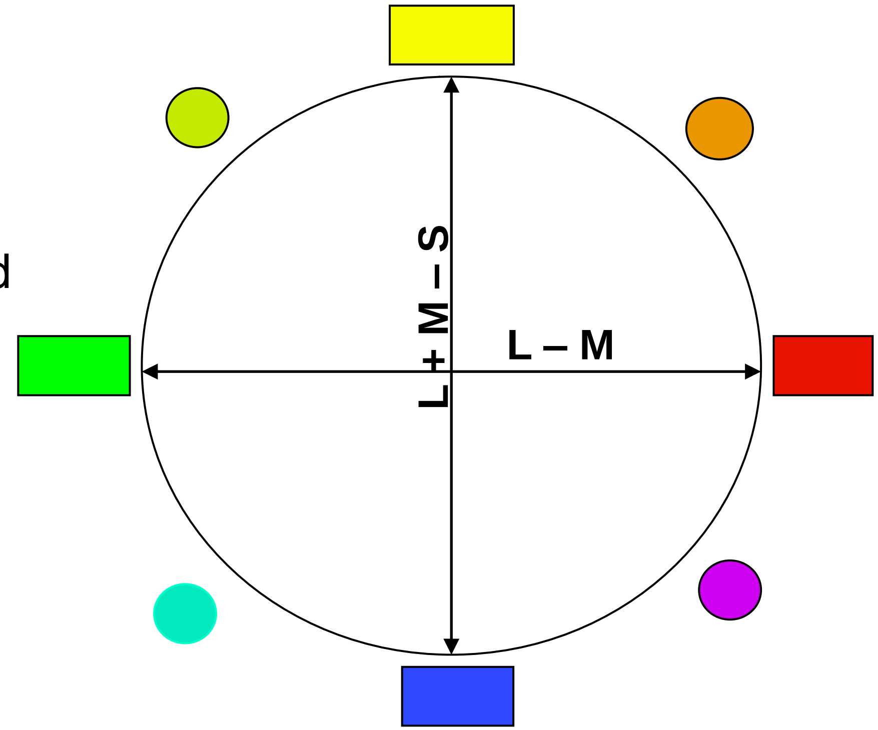
•There are also four ‘binary hues’ – **orange** (reddish yellow), **purple** (bluish red), **turquoise** (greenish blue), and **chartreuse** (yellowish green). These hues look essentially mixed.

•However, there are ‘spectral opponences’ between red and green and between blue and yellow. This means that there can be no reddish greens or yellowish blues. There are physiological reasons for all this …

Photoreceptors and opponent processing

There are three kinds of colour receptors, or ‘cones’, in the retina: ‘**L**(ong)’, ‘**M**(edium)’ and ‘**S**(hort)’. Their sensitivity curves peak at different parts of the visible spectrum.

However, it is the **differences** between stimulation levels (at a given point) that the brain is especially geared to notice:



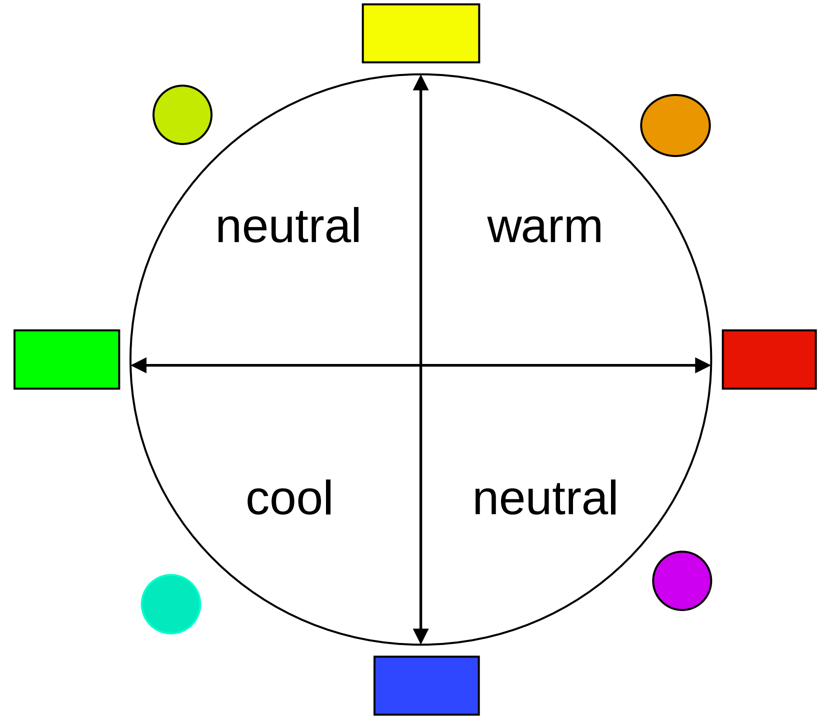
If **L** – **M** > 0 (i.e. the **L** signal is stronger than the **M** signal), the red–green channel is **excited**, and the hue looks reddish (at that point);
If **L** – **M** < 0, the red–green channel is **inhibited**, and the hue looks greenish.

If **L** + **M** – **S** > 0, the yellow–blue channel is **excited**, and the hue looks yellowish;
If **L** + **M** – **S** < 0, the yellow–blue channel is **inhibited**, and the hue looks bluish.

Excitation–inhibition dualities (“push–pull”) are known in physiology as **opponent processes**.

Binary hues result from combining activity from both channels.
However, since a channel cannot simultaneously be excited and inhibited, it follows that we cannot perceive reddish greens or yellowish blues **(except in extraordinary circumstances).**

Warm versus cool hues



•Some hues (red, orange, yellow) seem intrinsically **warm** (“advancing”, “positive”); other hues (blue, turquoise, green) seem intrinsically **cool** (“receding”, “negative”).

•There are cultural and physical associations here, but also (it seems) pure phenomenology.

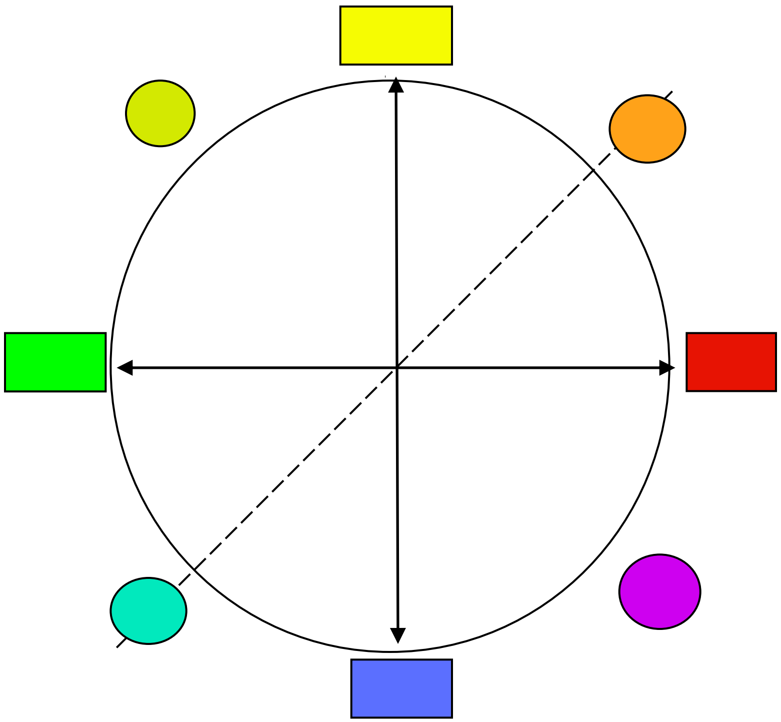
•As mentioned, perception of red/yellow involves **excitation** of neural pathways; of green/blue, **inhibition**.

•There is some (controversial) evidence that this excitation and inhibition has a wider physiological impact, which could **perhaps** explain these phenomenological features.*

*See, for example, Peter K. Kaiser (1984), ‘Physiological Response to Color: A Critical Review’, in *Color Research and Application* 9, pp. 29–36.

Hue-inversions (*aka* inverted spectra/*qualia*)

Simple red-green (r-g) inversion involves reflection in the vertical axis: the **L** and **M** receptors need to exchange their functions.



'Diagonal' (d-) inversion involves reflection in the dotted axis: the red-green (**L** – **M**) and yellow-blue (**L** + **M** – **S**) opponent-processes themselves need to be interchanged.

Red is thus exchanged with yellow, and green with blue. Orange and turquoise stay fixed.

Unique (binary) hues stay unique (binary), and warm (cool) hues stay warm (cool), thus ensuring that d-inverts are less easily detected than r-g inverts.

Supersaturated Yellow

Yellow is lighter and has less intrinsic saturation (or ‘chromatic content’) than red, so in order to maintain spectral parity we must suppose that d-inverts can perceive **supersaturated yellow**, a colour which relates to yellow as red relates to pink (in other words, ‘**???**’, as we put it).

	?
	??
	???

We cannot perceive this. They (d-inverts), likewise, cannot perceive ‘supersaturated pink’ (i.e. red).

D-inverted photographs can almost depict supersaturated yellow by simply desaturating all non-yellows. This ensures that only hues are altered, and that relative brightness and chroma levels are maintained. (This can be difficult to achieve in practice, however, alas.)

The ‘D-Project’ (1)

- The **d-project** aims to ensure that normal perception can be routinely contrasted with its d-inverted version: ideally by developing d-inverting spectacles; more realistically, by regular hue manipulation of digital photographs.

- By developing this contrast, we obtain a clearer conception of what needs to be **explained** -- that colours look like (a) rather than like (b), for example.

(a)

(b)

“Dead Man’s Walk”, Oxford, seen from Merton College.

The 'D-Project' (2)

- The **d-project** also aims to develop a phenomenal language that characterizes the differences between hues and their d-inversions. In particular, it aims to fill in the '???' boxes.

- We can then (perhaps) start to connect phenomenal facts with their neurological correlates in a way that crosses the 'explanatory gap'.

Warm **Advancing** **Positive**	**Cool** **Receding** **Negative**

???	**As opposed to …** **???**

Colour editing methods

There are many ways to alter the colours in a digital photograph. *Adobe Photoshop* is a comprehensive and readily available software package, and is very good at selecting portions of the spectrum and varying either hue or lightness. It is also fairly easy to learn how to use. However, accurate portrayals of red-green or diagonal inversions require reflection of the colour circle in a diameter, and most software packages (including *Adobe Photoshop*) instead only rotate selected arcs. This yields the wrong results in cases where hue itself (and not just lightness) varies continuously, for example with skies and sunsets.

An alternative package is the less well known *xv color editor* (see http://structbio.vanderbilt.edu/chazin/wisdom/xv-3.10a/color-editor.html), which does enable reflection in a diameter as well as expansion and contraction of selected arcs of the colour circle (it is the only software package that I have come across that can do this). Red-green inversion can be accurately performed with a single edit, though diagonal inversion is more complex. This package is much harder to learn to use, does not lighten red to pink or deepen yellows, as is required for diagonal inversion, and is unavailable in Windows. However, if you are not yourself technically savvy, your technician will be able to build you a virtual machine which will operate the Linux or Fedora program on an ordinary Windows computer, but it requires a lot of work.

The best results can be obtained by using firstly the *xv color editor*, followed by fine-tuning with *Adobe Photoshop*.

Illustrations

View from study window, with d-inversion.

Illustrations

Holy Island, Northumbria; with red-green and diagonal inversions.

London street with inversions

Illustrations

Abbey at Lindisfarne, Northumbria; with inversions.

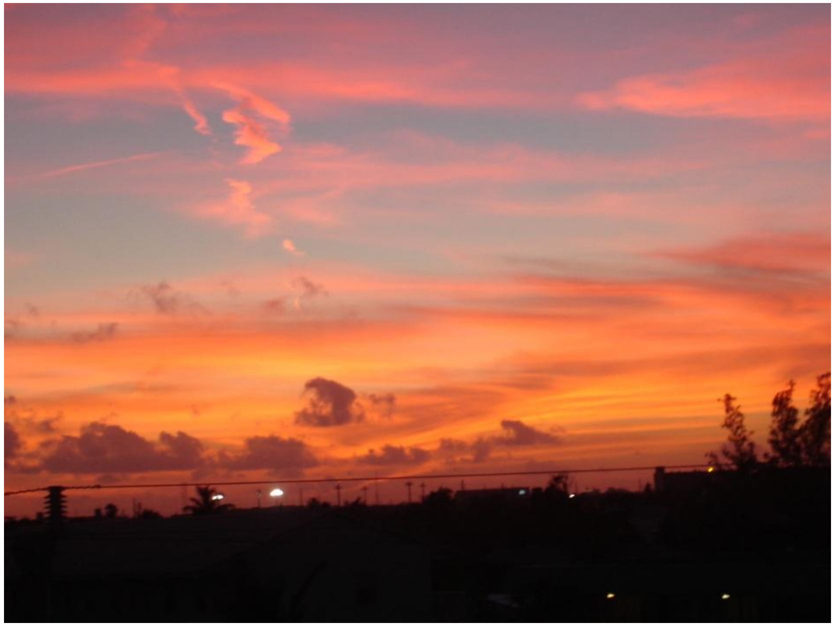
Illustrations

The Backs, Cambridge, seen from Clare Bridge; with inversions.

Illustrations

Rivington reservoir, near Bolton; with inversions.

Illustrations



- Florida sunset with inversions

Illustrations

- Hawaiian sunset with inversions