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Colour magic: additive mixing and coloured shadows

How we perceive colour

Colour mixing

According to the theory of colour vision, developed by Thomas Young and Hermann von Helmholtz in the 19th century, we experience colour thanks to three different types of receptor cells (now known as cones) in our retina, each of which is most sensitive to red, green, or blue wavelengths of light (see figure 1). Young chose three principal colours because he found that he could produce any colour of the spectrum (as well as white) by a mixture of three overlapping lights set to appropriate intensities. He also found that this could be achieved with a range of wavelengths; this means there is a certain degree of arbitrariness to the definition of the three primary colours.

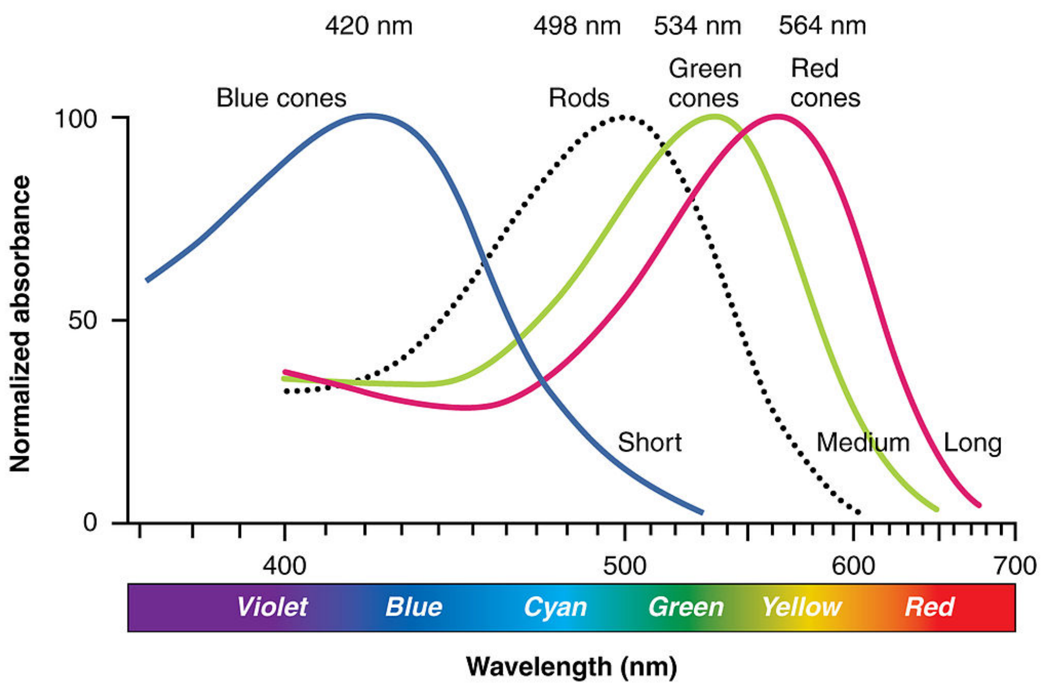

Figure 2: Modern-day experimentally determined responsivity spectra of the three types of human cone cells (normalized).
Image: Anatomy & Physiology, 2023, OpenStax

The Young–Helmholtz theory has led to the development of the so-called red, green, blue (RGB) model. The RGB model was applied in the first experiments of early colour photography, and it is used today to produce colour in computer, television, and mobile phone displays.

In additive colour mixing, combining the three primary colours, red, green, and blue, in equal proportions yields white, whereas mixing any two primary colours in equal proportions yields the so-called secondary colours: yellow, cyan, and magenta. When the additive mixture of two colours produces white, these colours are said to be complementary that is, cyan and red, magenta and green, and yellow and blue.

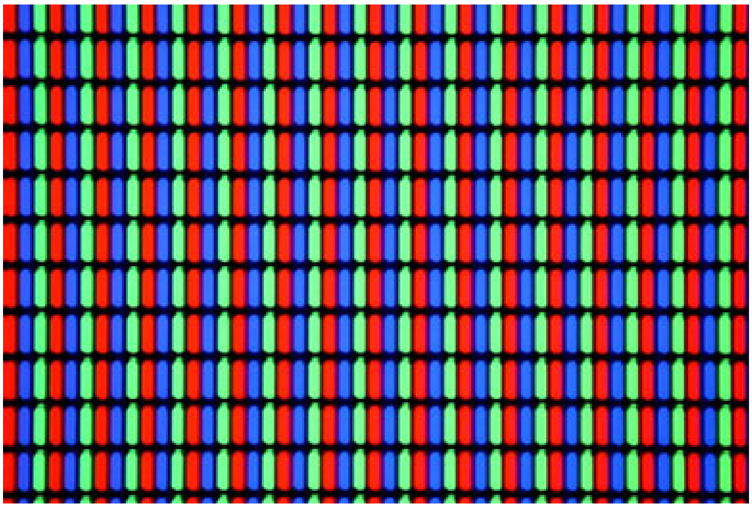

Figure 2: This is what a blank, white phone screen looks like under a microscope! The red, green, and blue light that makes up each pixel is visible. This screen has 424 pixels per inch, meaning that each pixel is around 60 microns. For comparison, a sheet of paper is about 100 microns thick.
Images: LCD screen: Dome Poon/Fickr, CC BY-NC-ND 2.0

Question: Figure 2 shows a magnified image of a blank (white) phone display. What would you expect to see if the screen were green? What about if the screen were blue?

What colour does mixing red and green make?

It is important to understand that there are two types of colour mixing:

- **Subtractive colour mixing**, in which **pigments**, such as paints, clay, or ink, of different colours mix to produce other colours. These pigments absorb colour, and thus, subtract a colour from the reflected light.
- **Additive colour mixing**, in which **light** of different colours mixes to produce new colours, for example, the red, green, and blue light making up each pixel in our screens.

For comparison: the subtractive mixture of red and green pigments produces a *brown* colour, whereas the additive mixture of red and green light produces a bright *yellow*.

Our activities today demonstrate additive colour mixing.

Figure 3 shows the results of additive colour-mixture pairs of the **primary colours** red, green, and blue. The resulting colours are called **secondary colours** (yellow, cyan, and magenta).

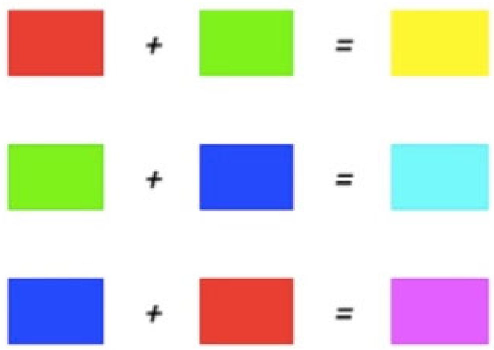

Figure 3. Additive mixing of two primary colours (red, green, or blue) produces the so-called secondary colours (yellow, cyan, and magenta).
Image courtesy of the author

Question: Having taken a look at the colour table in figure 3, what would you expect to see in a microscope image of a screen showing a yellow colour?