A simple spreadsheet tool for matching colours against standards

Jerry Cooper, Christchurch, New Zealand, July 2025

Introduction

This document introduces a simple spreadsheet tool allowing you to match digitally captured colour information against several of the widely used standard colour charts, like Methuen and Munsell. It was constructed to help me describe the colours of fungi for formal descriptions of new species. Modern species descriptions should include accurate colour photographs but there is still a place for these standards, and the terms used in older literature need interpretation. In general, I would recommend including the hex code for a colour, along with the nearest standard colour name of your choice. The spreadsheet may be of use to others.

The physics & physiology of colour

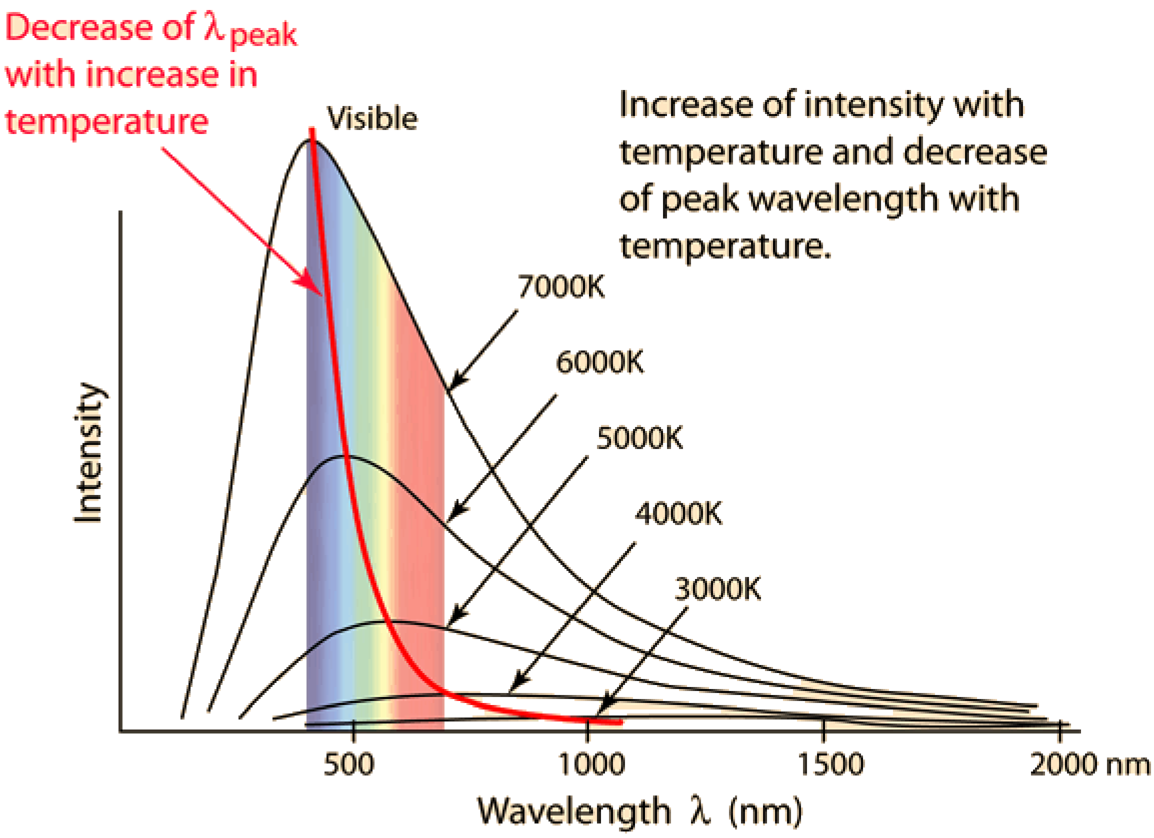
In searching online for existing tools, I was disappointed by the degree of misunderstanding of what colour really means. I was originally trained in physics, and the human perception of colour is one of many examples where physics and physiology intersect. As physicists we construct mathematical and descriptive models that attempt to explain and predict the behaviour of objects and events in physical reality. But what do we mean by physical reality? Do we mean a directly intangible, universal thing, out there, that we each perceive, in different ways, with a pathetically small range of senses feeding a brain that is very good at filling in the blanks? Certainly, whatever models we construct must consider what those senses can, and cannot tell us, and consider what tricks our brains might play to construct our internal perception of reality. The perception of colour requires this context.

Colour is not a property of physical reality but rather it is the term we use for our perception of something filtered through the human sense of vision. In addition, when we try and discuss colours with others then our language is, quite literally, coloured by our cultural heritage. A common understanding of what we mean by colours, and the names of various colours, can be elusive.

From a physics perspective colour perception is complex process involving characteristics of the light source, the surface of the object being illuminated, the human eye, and how the brain interprets the signals from the eye. Then there are the extra stages involved when colour is captured by a camera and how that data is rendered on computer screens and printing.

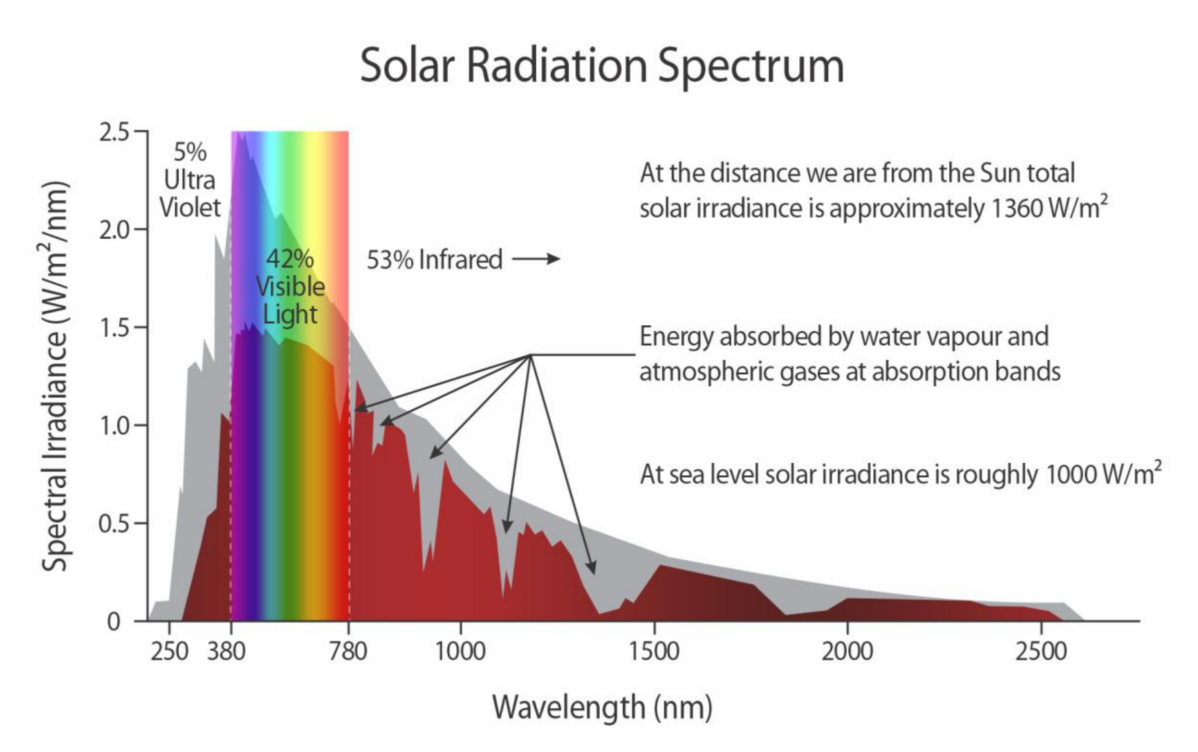
The chain of events starts with the illumination of an object by a source of light. Often that source of light is the sun which is essentially a hot ball of gas. All objects with a temperature greater than absolute zero emit electromagnetic radiation, a small portion of which we can see as visible light. Electromagnetic radiation, when considered as a wave, is characterised by its wavelength. Short wavelengths are gamma rays with increasing wavelengths spanning through X-rays, ultraviolet, visible light, infra-red, microwaves and longer wavelength radio-waves. A light source will have a characteristic spectrum showing the amount of radiation as a function of wavelength. Hot bodies have a characteristic spectrum which in physics is called a blackbody radiation curve. The term blackbody is perhaps a bit misleading, but it really means the radiation purely due to temperature and not due to the intrinsic properties of the material. So, for example when you heat a poker in a fire it will start to glow dull red, then orange as it gets hotter, and finally white hot. Gold is yellow at room temperature, not because of its temperature but because of its intrinsic properties.

Here is the theoretical form of the blackbody spectrum as a function of temperature:



http://hyperphysics.phy-astr.gsu.edu/hbase/wien.html

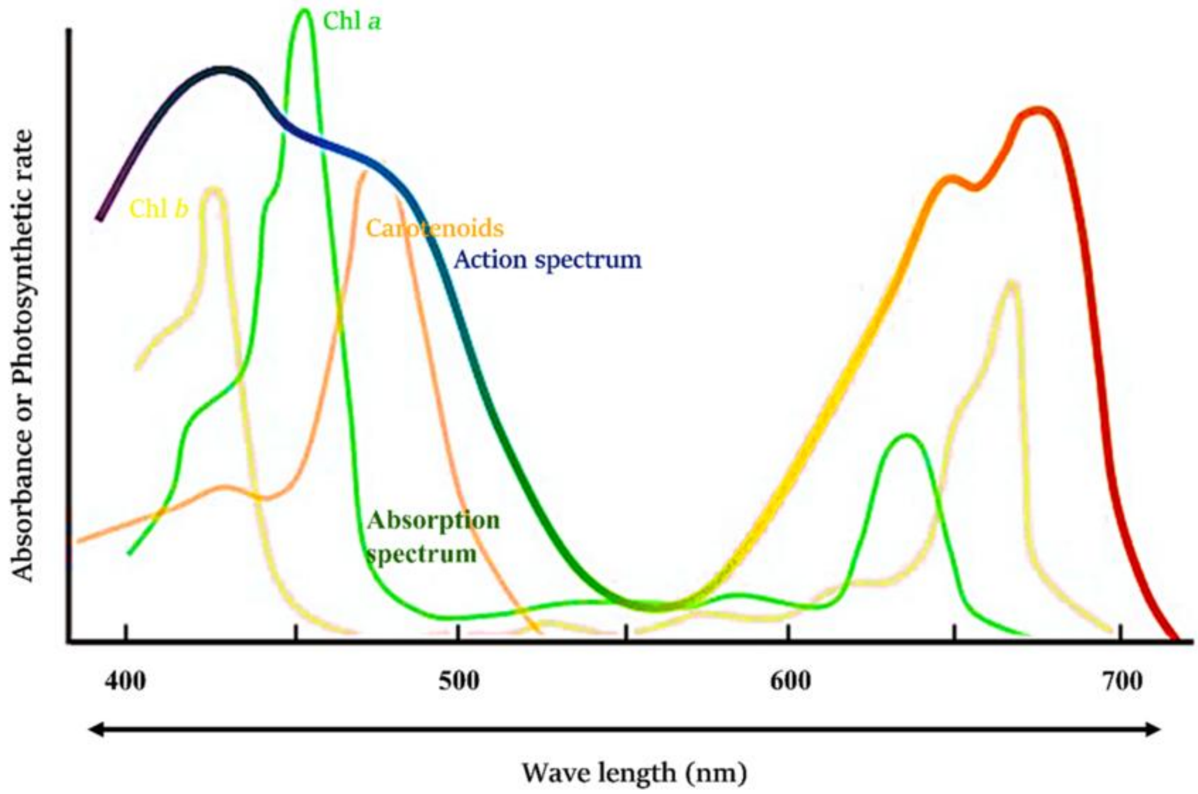
And here is the spectrum of light from the sun at the earth's surface:



https://sunwindsolar.com/blog/solar-radiation-spectrum/

The sun corresponds approximately to a blackbody radiator with a temperature of 5,000 °C.

But note the curve is not smooth and that's because water vapour and other gases in the earth's atmosphere selectively absorb at certain wavelengths. When you are under the leaf canopy in a forest then chlorophyll in the leaves selectively absorbs reds and blues, greatly shifting the colour of light illuminating objects:



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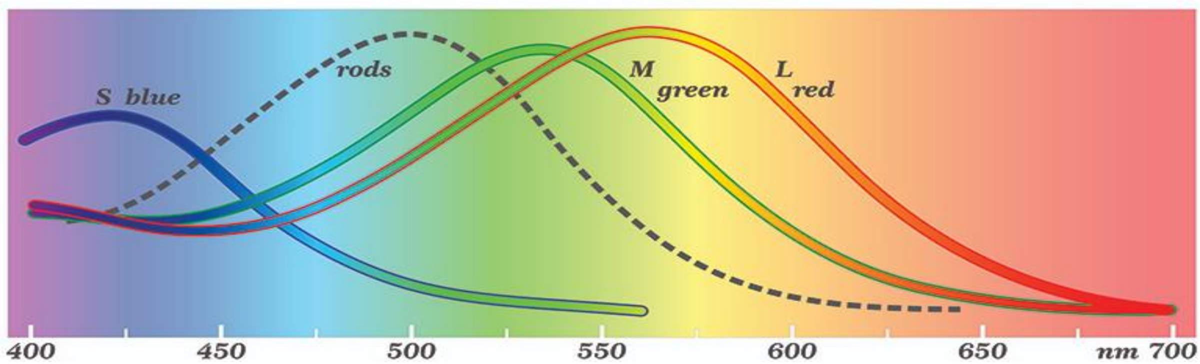
At a much finer level there are tiny gaps in the sun's spectrum where light has been absorbed by gases in the sun, and in fact the element Helium was first discovered in the solar spectrum before it was isolated on earth

The colour you perceive for an object depends significantly on the range of wavelengths illuminating it, and what parts of the spectrum the object itself selectively absorbs.

The next stage is what happens in the eye. We all learn at school about rods and cones. Cones detect colours and rods are sensitive at low light. The cones (in humans) are of three types that are sensitive to red, green and blue:



https://www.datacolor.com/business-solutions/blog/the-role-of-rods-and-cones-in-color-perception/

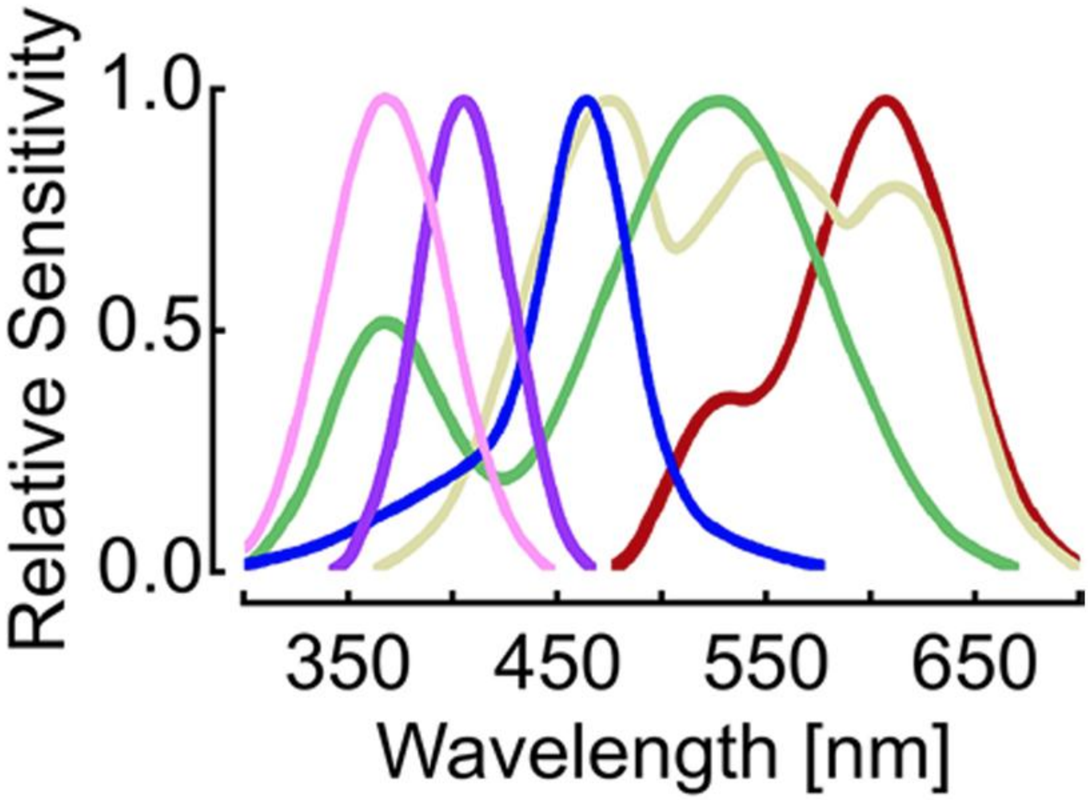
Each type of cone is most sensitive at some wavelength and the sensitivity drops off either side of that central peak. It is important to understand that your eyes are not seeing the entire spectrum of radiation reflected or transmitted by an object. Your eyes are sampling components of the available spectrum in the visible range and with varying sensitivity across that range. The combined sensitivity of the three cones matches the peak spectrum of the sun, and that is obviously not a coincidence.

The real magic occurs in the brain where the red, green, blue colour nerve signals from the cones are synthesised into your perception of colour, and your brain is very good at filling gaps. So, for example, a surface that appears yellow will be emitting light at about 580nm, but you don't have cones that are tuned specifically to 580nm (the so-called 'red' cones are not far off). If you look at the last graph you see that 580nm occurs way down in the right-hand tail of the blue cones, to the right of green cones and around the peak of the red cones. 580nm will generate a low blue-cone signal and reasonable red & green-cone signals. This mix of cone signals is what your brain turns into the perception of yellow. The brain is capable of distinguishing about a million different red/green/blue signals, i.e., about a million different colours.

The red/green/blue mix of cone signals means that the brain can be fooled into seeing colours that aren't present in the light source. If you have a light source that mimics the amount of red, green and blue signals (primary colours) that 580nm stimulates in the three cones, then your brain perceives yellow (a secondary colour), even though pure yellow at 580nm is not present in the light source. Of course that is exactly what colour screens do. They all have small dots that emit red, green and blue primary colour components that can be made to fool the eye into seeing colours that aren't there. The same process is happening in a digital camera. The camera's sensors are not sensitive to all wavelengths, rather they sample the spectrum with red, green and blue filters. Ideally the filter sensitivity to each of the three primary colours should exactly match the three cones in the eye, but they rarely do. For that reason, the colours captured by a camera can mismatch what you perceive with your eyes, and that is especially true if the spectrum of light from an object contains 'spikes' at certain wavelengths. Purple hues (e.g. *Pulchericium caeruleum*) seem to be prone to mismatch.

And then finally, the red-green-blue data in a digital colour image needs to be rendered faithfully on a computer screen. Usually colour monitors aren't good at doing that and they have substantial variability. I use professional full-gamut colour monitors, and they are regularly calibrated to ensure they render colour faithfully (using a Spyder sensor).

It is worth noting in passing that human tricolour vision isn't very good compared with many animals. Here is the spectral sensitivity of a butterfly:



https://link.springer.com/article/10.1007/s00359-019-01397-3

This butterfly has 6 classes of cones that are sensitive far into the ultraviolet and further into the infra-red. What the butterfly sees has little resemblance to what we see. Other butterflies have as many as 15 sets of colour receptors.

Labelling colours

Whilst the human eye/brain is capable of distinguishing over a million colours (the visible gamut) using our paltry three sets of receptors, it doesn't help much if we can't communicate our perception of colour to others. We don't need a million labels, but we do need some, starting with the ubiquitous rainbow colours of red, orange, yellow, green blue, (indigo), violet. The indigo in brackets because it was added by Isaac Newton to pad out the number of colours in the rainbow to a magical number 7.

It is human nature to classify and label the phenomena around us, including colours. It is the taxonomist's job to do precisely that for organisms. It is therefore hardly surprising that colour classification has played an important role in how mycologists describe fungi. Mycologists adopted the colour nomenclature invented by others and those they invented themselves. So, like most 'standards', there were no shortage of alternatives to choose from.

Many of these colour standards have dual roles. The first role is the provision of some kind of coding system (a notation) to designate many (all) perceived colours, and the second role is to provide a set of standard terms (meaningful words – a nomenclature) for a subset of colours.

The coding system must capture colours the eye sees, and the brain interprets, and, as I indicated earlier, that is simply down to the level of nerve signals being stimulated in the red(R), green(G), blue(B) cones. The mix of RGB defines the hue of the colour, and the intensity of the signals defines the saturation of the colour, i.e. the brightness.

The various nomenclatures for labelling and communicating colours are naturally highly biased by culture and history. Some colour names in common use 100 years ago in the west now appear offensive or meaningless. In addition, the names used between various systems can be the same, but their meaning vary between those systems.

Ridgeway 1912

One of the earliest generally adopted notations was published by Ridgeway (1912). Ridgeway divided the visible spectrum into sets of reds, oranges, red-oranges, yellows etc. He also provided a system for indicating the brightness of a colour and the shades of grey dulling applied to a colour. Using this general notation, he published a limited print run of books containing a set of 51 plates, each with 27 coloured tiles, and each tile coded according to his system, and with a set of standard names (1,115 of them). A big problem with the Ridgeway publication is that tiles in different copies of the book have aged differently and the colours now rather variable. The Ridgeway notation was reasonable, if unscientific.

Munsell 1905/1929

Earlier than Ridgeway, Munsell published his version of a notation based similarly on values for hue (colour), chroma (the greyness) and value (brightness). The Munsell system was mathematically reasonably well-defined in the sense that his notation for colour defined unique coordinates in a multi-dimensional 'colour space'. That formulation facilitated the familiar tools of the colour wheel and colour sphere still extensively used to allow users to intuitively navigate 'colour space'. The original formulation needed some mathematical tidying up but led to the publication of The Munsell Book of Colour in 1929. Like Ridgway this had sets of coloured plates, and by this time printed colour reproduction had advanced sufficiently that variability with ageing was reduced. Munsell provided a useful, universal notation system that could encode any colour, and printed book with a set of such colours, but the original publication did not apply a nomenclature to them. Subsequently the Munsell system was used to publish sets of named plates for specific uses, such as the Munsell soil series.

Methuen Book of Colour 1963/78

Fast forward to 1963 and the publication of the Methuen Book of Colour by Kornerup & Wanscher. The 1978 3rd edition has become the colour standard for most taxonomists describing the colour of fungal species in the latter part of the 20th century. It remains a very expensive second-hand book. Kornerup & Wanscher invented yet another notation and nomenclature and they did not cross-reference all the colours to other existing standards, although the 2nd edition contains a subset of matches (just A8 chips) to Ridgeway codes, and the 3rd edition similarly to CIE codes. Ron Petersen later provided a useful 'by eye' concordance between the many more of the colour chips of Methuen (2nd ed.) and the codes and names used in his copy of Ridgeway.

https://fungimag.com/winter-2016-articles/LR_V8I5%20Color.pdf

Mycology specific standards

The earliest attempt at a mycology specific standard was Saccardo's Chromotaxia in 1894, but there were no print runs of coloured tiles, and it never achieved widespread use. Mycologists quickly adopted the broader Ridgeway and Munsell standards.

There have been a range of mycology specific standards and Petersen mentions many of them in his publication.

In 1949 The Commonwealth Mycological Institute published Dade's Colour Terminology in Mycology. Dade based his colour charts on one version of Ridgeway, with the consequent issues of variability. In 1969 the Royal Botanic Garden Edinburgh published a small colour chart to support their publication of Flora of British Fungi by Roy Watling and others. The chart contains 80 named tiles and is not cross referenced to any of the existing published standards. In 1970 the Commonwealth Agricultural Bureaux published Rayner's A Mycological Colour Chart, based on Munsell codes, with 128 tiles. It also contains a complete set of concordances between Ridgeway names/codes and equivalent Munsell codes. It actually contains two sets of Munsell equivalents for Ridgeway. One set was based the copy of Ridgeway owned by CMI and the other set based on a copy of Ridgeway owned by D.H. Hamly. The codes are quite different in places, indicating that different copies of Ridgeway have aged differently, despite what some publications may say. The Rayner chart has been used widely, although not as frequently as Kornerup & Wanscher.

The modern digital era, CIELAB and sRGB

Several modern mathematically robust systems exist for encoding colours. For example, CIELAB (https://en.wikipedia.org/wiki/CIELAB_color_space). A more commonly encountered system is RGB where, simply, the three primary colours are mixed to mimic the gamut of perceived colours. In the digital world the RGB components are set by an 8-bit integer taking the values 0 to 255, and consequently can define around 16 million different combinations, exceeding the number we can perceive.

We must be careful to note the limitations of the RGB notation compared with a general and universal notation like CIELAB. How an RGB triplet is rendered depends heavily on the characteristics of the device doing the rendering. And what precisely do we mean by the red, green and blue primary colours? To manage this variation RGB notation should be specific to a particular set of devices. sRGB is perhaps the mostly commonly used variant used for monitors and digital cameras. These devices are not capable of rendering the entire visible gamut, but good enough for most purposes. A second problem is that increments in RGB 'space' are not linear with respect to our perception of colour change (whereas CIELAB distances are). An analogy would be like considering colours to represent points on the surface of the earth where we want to move a fixed distance north and fixed distance west. RGB is like having a paper map that is a projected transformation of the curved surface of the earth onto a plane. The map projection can take various forms, perhaps to ensure angles on the map are the same as angles on the sphere, so you can navigate with a compass (e.g. a Mercator projection). But on such a map a fixed distance north and east puts you in a different place to a fixed distance north and east on the sphere. The angles are correctly projected, but distances are not. The result for the RGB notation is that shifting incrementally through RGB values does not linearly shift you through the perceived gamut of colours.

The spreadsheet tool

The tool has tabs containing basic RGB encoded information for several of the standards discussed above. You provide a sample of the colour you want to match, and the spreadsheet calculates the colour distance to the tiles and orders them with decreasing similarity. You will need to accept the enabling of macros in the Excel spreadsheet.

The spreadsheet uses 'colour distances' in RGB space to ascertain the ranked similarity of colours. Sometimes the ordering of the results looks odd, and there are two reasons. Partly it is the non-linear representation of colour distances in sRGB, as noted above. It would have been possible to convert all colour distances into a linear standard, but I felt the complication not worth considering. However, mainly it is because the calculated colour distance is a scalar. The top nearest colour might be in blue direction, the next top in red direction and the next in the green, and so on. If the colour distance is greater than 10-15 then you don't have a good match.

Be aware the corresponding-coloured cells in the spreadsheet may not match the actual colour. As explained previously, how colours are rendered depends on your hardware, however, that does not impact the calculation of the colour distance. It is only important that the original sampling is correct. Do not be tempted to try and match your coloured object directly against coloured tiles in the tabs. They are there simply to comfort you the tool is doing its job.

Typically, the object colour sample would probably come from a digital photograph. The colour of a pixel or area in an image can be sampled using many tools. I generally use the eyedropper tool in Photoshop (copy & paste) but there are several online tools that can do the same. The spreadsheet needs the hex format for the colour rather than RGB triplet, but I included a converter.

Ideally of course the colour would be sampled directly from the object, and for that I recommend the Nix range of affordable colorimeters.

https://www.nixsensor.com/

The cheaper Nix model (Nix3 mini) was used to capture many of the tiles used in the spreadsheet, but you wouldn't use that cheaper model directly on a mushroom.

In the spreadsheet I have relied heavily on the available software tools for interpolating between different standards, and especially RGB and Munsell.

https://rdrr.io/rforge/munsellinterpol/

Notes on the data contained in the colour standard tabs

Pantone

Pantone is a company that specialises in supporting the use of colours in the manufacturing industries. They provide a managed nomenclature of currently 2,161 named colours and a notation that can be applied to printed products, electronic displays, manufactured goods etc. The Pantone colours can lie outside the range that can be rendered with sRGB compliant devices. Pantone nomenclature has become a de-facto globally accepted standard. The company claims IP over their nomenclature, although it seems hard to understand how names like 'Emerald' or its specific rendition into RGB notation can be considered IP. The result is that RGB notation for Pantone colours is not considered to be public property. The colours I have used are Pantone-like, scraped from the web, and may not exactly correspond to their proprietary standard.

Methuen

The colour plates of a reasonable copy of Methuen 3rd edition were sampled using a calibrated Nix3 mini colorimeter. I have included the converted equivalent Munsell codes for each chip.

Flora of British Fungi

The colour plates from my very old copy of this chart were sampled using a calibrated Nix3 mini colorimeter. Some of the paler colours in the chart are incorrect and that was noted at the time of publication.

Munsell colours

For the Munsell main series and soil charts I captured the range of online available Munsell codes and used the 'munsellinterpolation' R package to convert those to the corresponding RGB triplets. I'm not sure now where I got the soil colours and codes from, and I'm not sure they are all correct.

The Online Auction Color Chart (OAC)

This colour standard I haven't included, but I could if I could unearth my old copy of it buried in too many boxes of old mycological books and journals. However, it is just a notation without a meaningful nomenclator. I guess it would be useful to turn OAC codes into RGB (which should have been done in the first place).