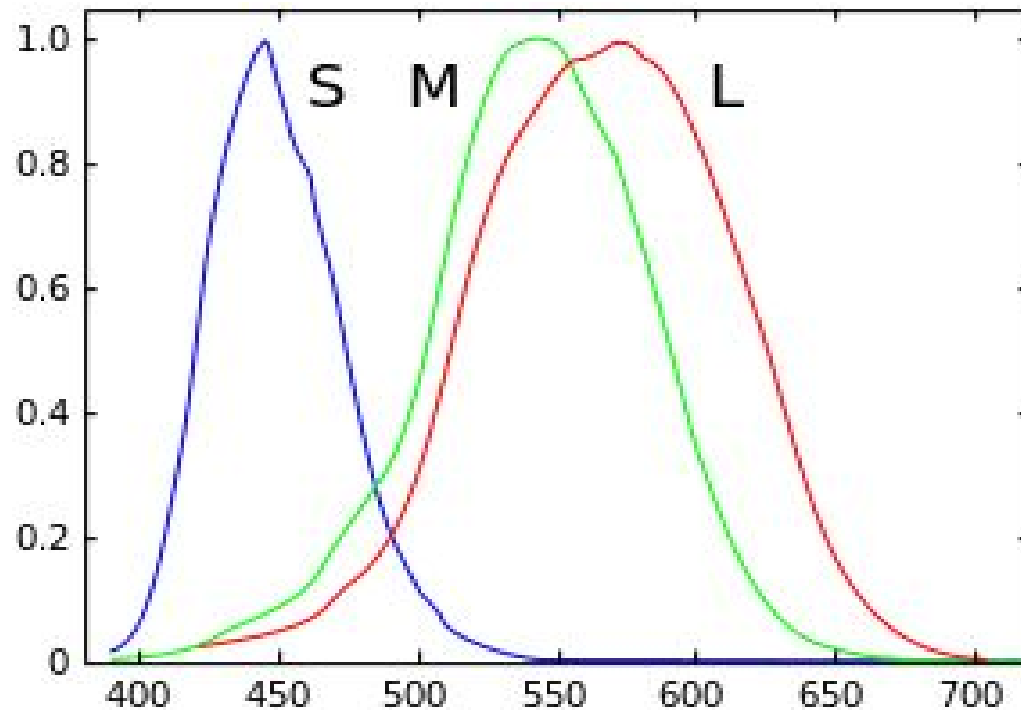


Colour Management Workflow

The Eye as a Sensor

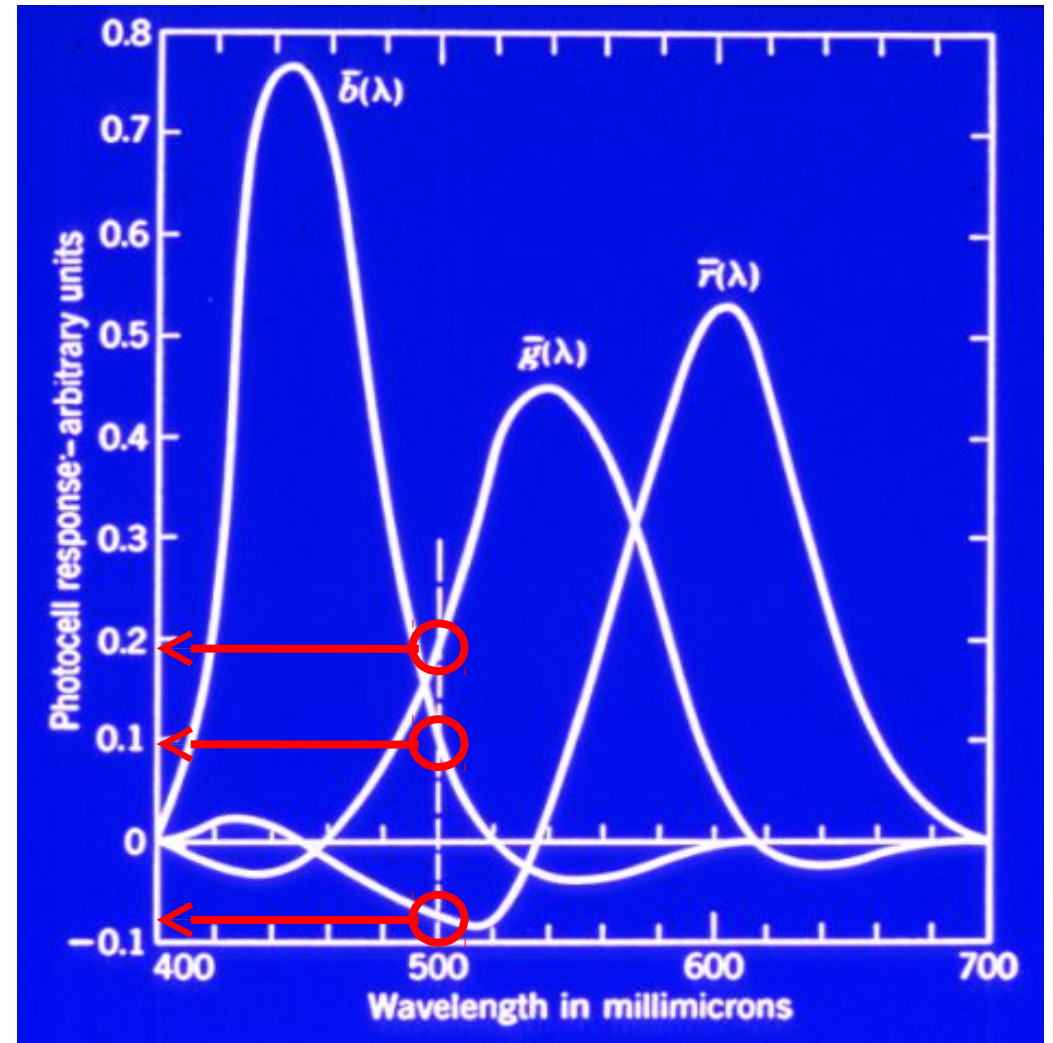
- The eye has three types of receptor called 'cones' that can pick up blue (S), green (M) and red (L) wavelengths.
- The sensitivity overlaps slightly enabling us to 'see' colour by a mixture of these wavelengths.
- But they only work under medium and high brightness. In dim light or at night other sensors called 'rods' take over that can only detect monochrome.



Colour Theory

- Color Matching Functions

- In 1807 Thomas Young developed three color matching functions, r, g, and b.
- These curves indicate the relative amounts of red, green and blue light required to match a desired colour (indicated by the horizontal axis).
- Example:
 - To match 500 nm (bluish green) requires -0.8 r, 1.9 g, and 0.95 b.



Colour Theory

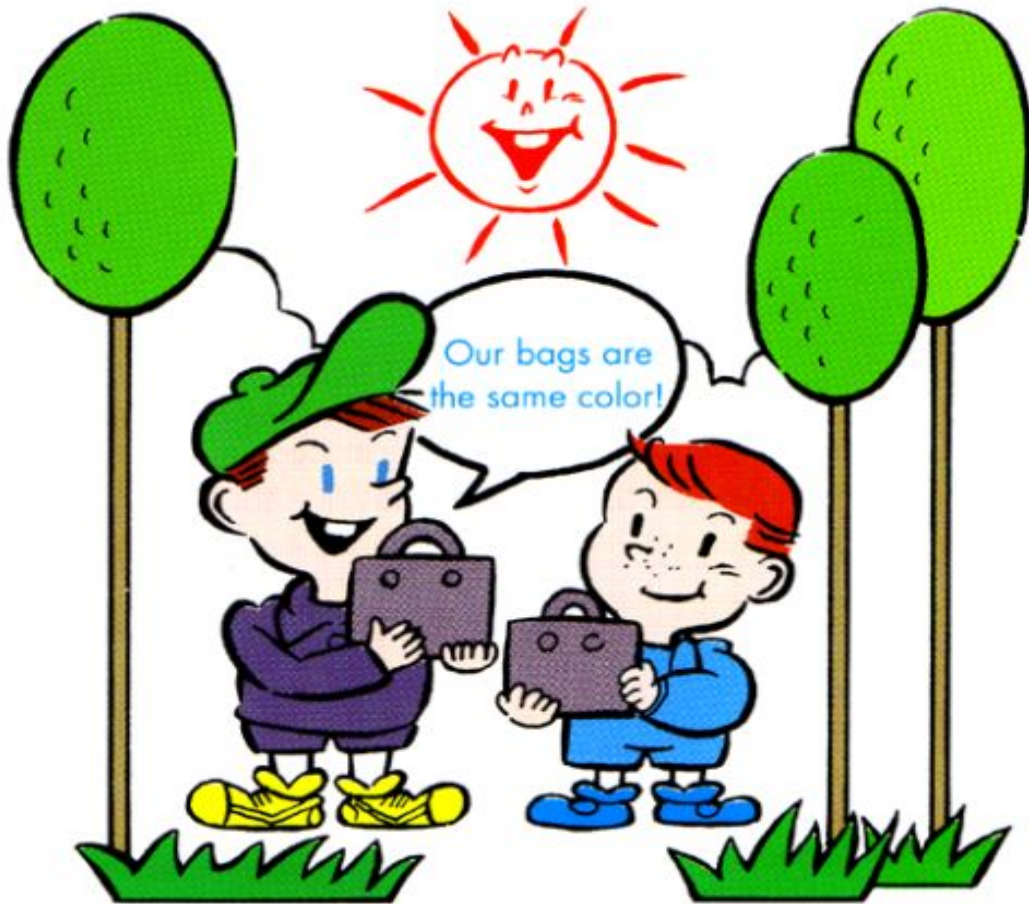
- Tristimulus Values

- The perception of colour is not only a function of the object's spectral reflectance, but is also affected by the illumination source and the sensitivity of the detector (eye or camera sensor).
- The X, Y & Z tristimulus values were developed to incorporate all three effects into a set of three values that uniquely characterize the human perception of colour under these viewing conditions.

Colour Theory

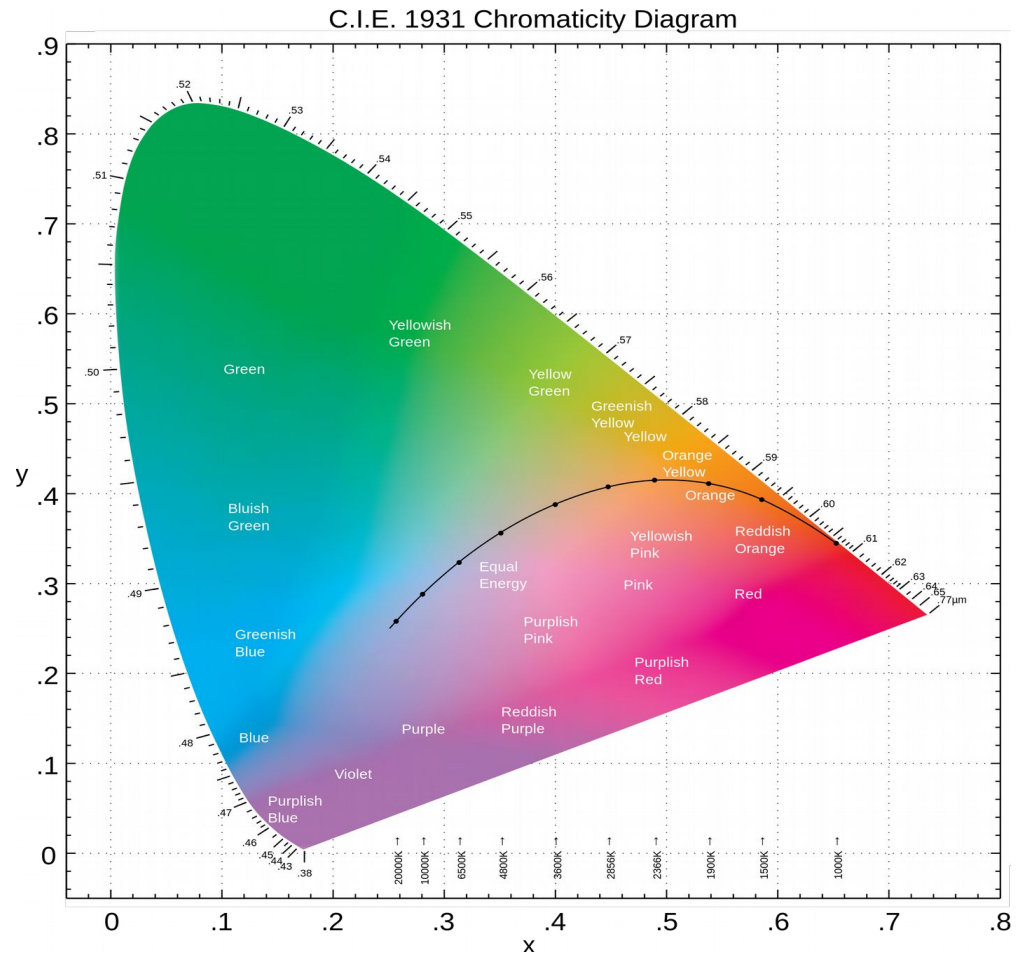
- Metamerism

- Phenomena where two objects with different reflectance spectra appear to be the same colour depending on light they are viewed in.



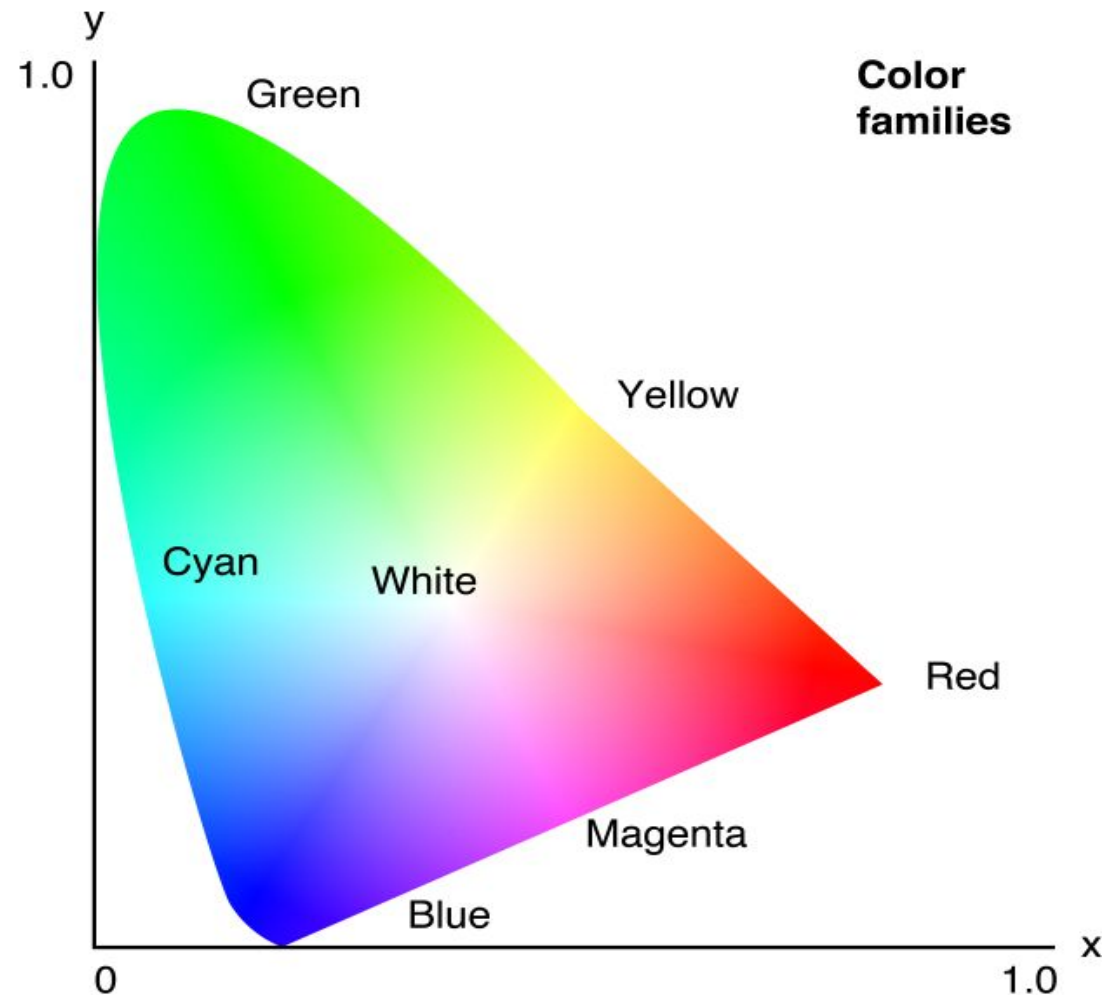
Use of Colour Perception to Create the Visual Colour Space

- The early experiments on colour perception lead to the CIE 1931 RGB and CIE 1931 XYZ colour spaces from the three 'tristimulus' variables in a 3-dimensional additive colour model.
- This is usually simplified as a 2-dimensional diagram in which all colour that can be perceived by a normal person is plotted.
- 'Pure' colours are on the outer edge, mixing to white in the centre.



The CIE 1931 Colour Space

- Under normal light people are able to perceive green light as brighter than red or blue. So this was chosen as the luminance measure in the diagram on the 'y' axis.
- Ratios of the three colours then form the 'chroma' on the 'x' axis.
- This forms the basis against which all other colour spaces are compared.

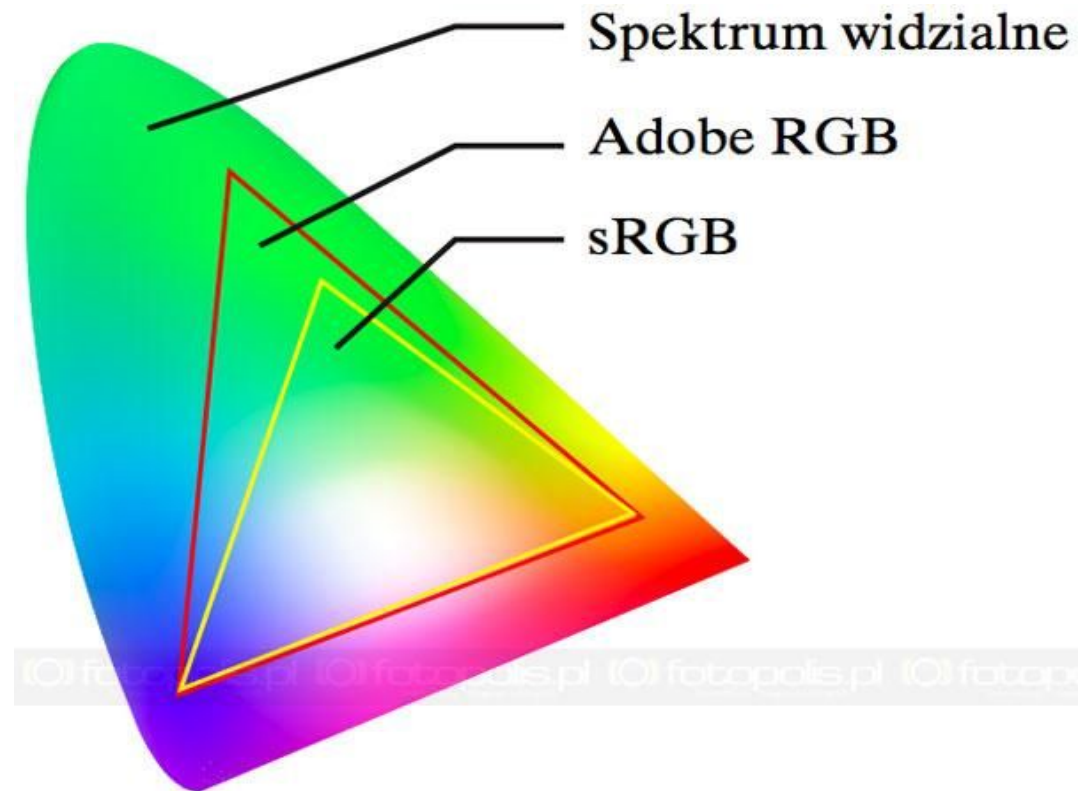


Ensuring Consistency Between Devices

- Devices used to capture, process and output images all respond to colour in different ways.
- Each device (camera, monitor and printer) is only capable of working within a sub-set of the visual colour space. This range is called the device colour gamut. Any colour outside this is referred to as being 'out of gamut'.
- The rest of this presentation will look deeper into what effect this has on the way we photograph and process our images if we want better consistency between the colours we saw in the scene and what we finally output.

Camera Colour Spaces

- Camera manufacturers try to emulate the eye by having red, green and blue sensors in their cameras with twice as many greens as blue or red.
- None are perfect and form a sub-set of the standard model.
- The two standard spaces built into cameras are AdobeRGB and sRGB.
- Note that sRGB is smaller than AdobeRGB.

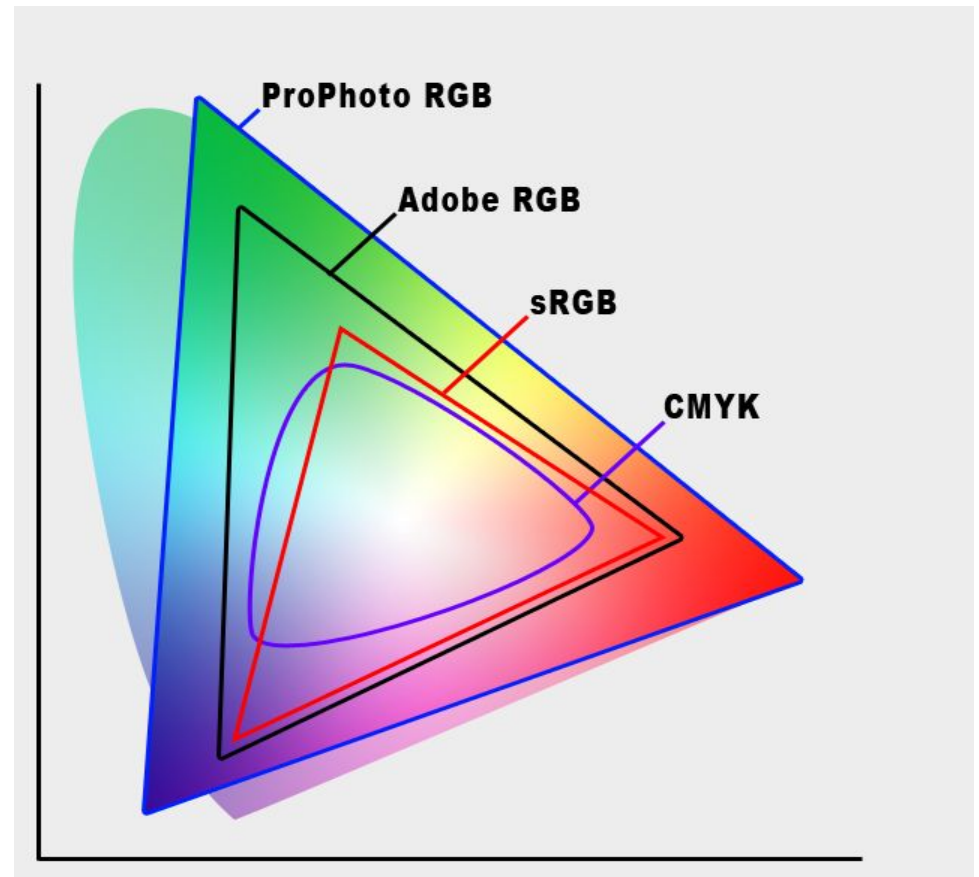


Variation in Colour Spaces

- AdobeRGB has a greater colour 'gamut' (collection of possible colours it can contain, but ...
- ... it does not contain more values, instead ...
- ... the values are spread over a larger range.
- For example an sRGB colour with R, G and B values of 130,210 and 130 would have the values of 156,208 and 133 in AdobeRGB to appear the same colour to the eye.
- A value of 130,210 and 130 in AdobeRGB will appear darker to the eye in a non-colour managed environment.
- The tools that photographers use such as Lightroom and Photoshop are colour managed so different colour spaces all appear to look the same on the PC monitor.
- As we cannot guarantee that images will be viewed on colour manage equipment images should be saved in sRGB in the final output.

Other Colour Spaces

- Many other colour spaces exist including ProPhoto RGB which covers almost the whole of the visual colour space.
- For printers the colour space varies depending on the printer, the paper used, and the ink (CMYK).
- Hue, Saturation and Lightness (HSL) is a major part of Lightroom to gain access to the various parts of the underlying colours. Photoshop can also be set to use HSL.
- 'Lab' is another major colour space worth getting to know. The 'L' is for lightness, the 'a' is the variation on the green to red axis, and 'b' is from blue to yellow.



Default Colour Spaces

- Photoshop and Elements uses sRGB.
- Lightroom uses AdobeRGB for everything except the develop module when ProPhoto RGB is used instead.

Colour Space Notes

- Converting from a larger colour space to a smaller one, e.g AdobeRGB to sRGB, can mean a loss of data due to the loss in size.
- Because larger colour spaces occupy a larger area processing is best done in 16-bit as opposed to 8-bit to avoid posterization.

The Camera

- The camera tries to emulate eye perception.
- It has red, green and blue sensors.
- It has twice as many green sensors as red and blue.
- Lightness tends to be more matched with green on the histogram.
- It always fails to match eye sensor, so don't be disappointed when colours don't match what you saw.
- Pixel count determines how many R, G and B group sensors there are.
- Bit count determines how many colours can be perceived.
- Pixel count and bit count determine the resolution of the camera.

Bit Counts

- For a workflow you may work in 8-bit or 16-bit per each R, G or B channel.
- Adding one bit doubles the number of colours per channel.
- 8-bit can contain 256 colours per channel (2 raised to the power of 8). This gives a total of 16,777,216 possible colours (256 * 256 * 256).
- 16-bit can contain 65536 colours per channel, or 281,474,976,710,656 possible colours.
- However ...
- Entry level cameras tend to have 12 bits so can record 4096 colours per each of the three channels. Pro and semi pro cameras tend to have 14 bits = 16384, i.e. they can detect four times as many colours per channel. Which is something to keep in mind when looking for your next camera.
- Much of the work in Photoshop requires 8-bit so there is always a data loss from what was collected in camera after any processing in ACR.
- As it was designed specifically for photographers Lightroom works with the full bit count of your camera (if working in RAW) until final output.
- Saving as jpeg in camera reduces image to 8 bits, which is a good reason for working in RAW whenever possible.

Camera Colour Temperature

- AWB is OK if scene colour matching is not required or critical.
- Selecting WB presets (e.g. Daylight) only works if the scene colour temperature is close.
- Better to use a grey card in one of two ways :
 - Use manual setting in camera – read your manual for this.
 - Take a photo of the grey card then use this in Lightroom/Photoshop as setting for all images taken under the same light.

Xrite ColorChecker Card

- Xrite card has a large grey patch (not shown in this image) for setting white balance.
- But it is also used for setting colour profiles under various light conditions for better colour matching using Xrites profiler which comes with the chart, or Adobe's DNG Profile Editor which you can download (right hand side of the image).
- It can also be used for artistic purposes. The grey patches give a basic WB, but adds a little red or blue for effects (left hand side).



The Monitor, Why and How to Calibrate

- Why calibrate? The monitor has red, green and blue phosphors that can vary over time and need to be adjusted in order that pixels in the image with a particular colour profile are displayed as such.
- For example if our monitor is too blue and we adjust an image so that it looks right to our eyes, when projected on a colour calibrated monitor it may look too red.
- Brightness and contrast are also affected and need to be set.
- Monitor quality varies, some are only able to show sRGB values and others AdobeRGB or even better for high end monitors. Laptops are probably all sRGB.
- How to calibrate? WHCC has a calibrator called the ColorVision Spyder. Its use is best shown in a practical session, however the instructions for use are straightforward and can be repeated many times if you get things wrong (choosing the wrong type of monitor for example).

Sizing Images for Showing by Projector

- For projection in camera club competitions your best bet is to size it to the size of the projector. i.e. for WHCC the image should be 1400 x 1050 pixels, or fit within this.
- So that for camera images in the 3:2 format this would be 1400 x 933 for landscape format, or 700 x 1050 for portrait (values may vary slightly on the minor dimension depending on the image).
- Using values greater than this will result in data loss as the image will be reduced to the projector dimensions by the projector and is therefore pointless.
- Images smaller than this will just appear smaller on the screen.

Setting PPI for Digital Images

- There is a lot of confusion about what to set the PixelsPerInch (PPI) value to for digital images, 300? 72? 90?
- Let me explain this once and for all:
 - It has no effect.
 - None.
 - Nothing.
 - It is irrelevant.
 - Forget it.
 - It does not matter.
 - The monitor/projector does not care.
- Got it?

The Printer

- Colour calibration for printing is the most problematic of all the devices as it is printer, ink and paper dependant.
- There are specialist tools to do it but I have never used them so I only know the theory.
- Instead you can often find ICC profiles for your particular combination online which does a pretty good job.
- To use them simply download and double clicking them will install after which they will be ready for use.
- To use a profile ensure that the printing is set to let Lightroom/Photoshop manage printing, and turn off colour management in the printer.
- Soft proofing is then the tool to use.

Soft Proofing in Photoshop

- Select View > Proof Setup > Custom
- Select the required ICC Profile as the Device to Simulate.
- Select Perceptual or Relative intent as required (see later).
- Select Black Point Compensation to preserve shadow details.
- You may want to leave Simulate Paper Colour unchecked. This optional setting is only useful if your monitor's brightness is set to a "print friendly" level.
- You can toggle the soft-proof on/off by using View > Proof Colors.
- Out of gamut colours will show as grey and can be toggled with Shift+Ctrl+Y.
- Adjustments is often done by changing saturation and/or hue values.

Soft Proofing in Lightroom

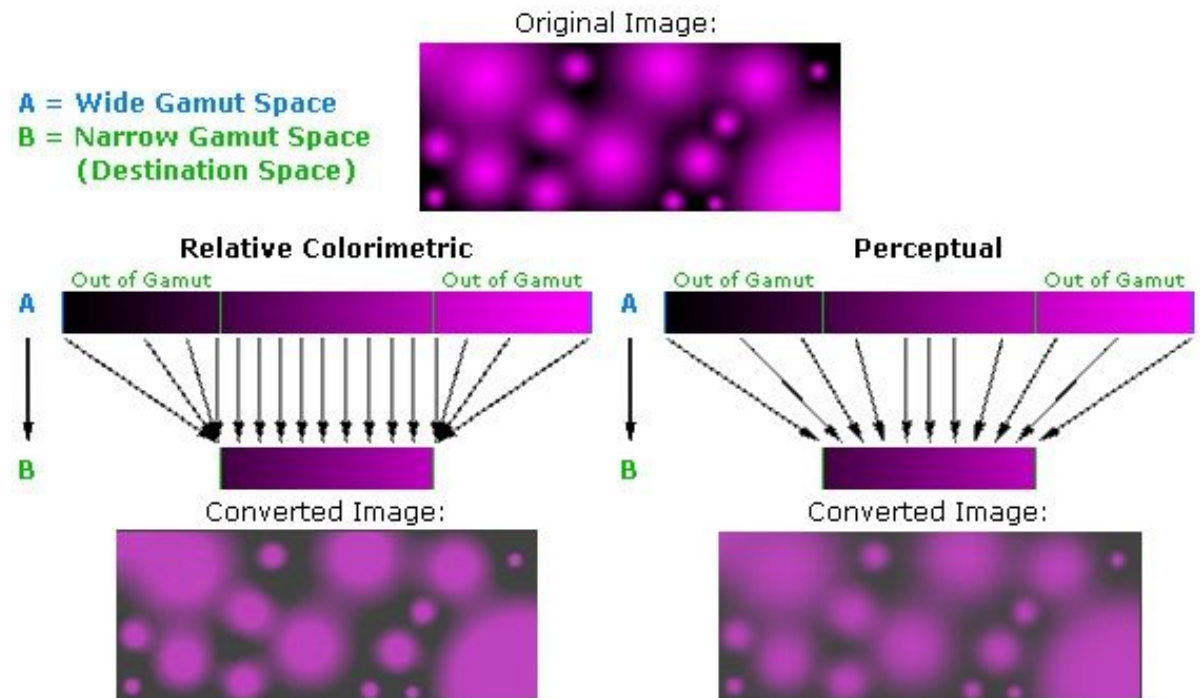
- In the develop module tick the 'Soft Proofing' box below the image.
- Select the required profile from the drop-down box that appears on the right of the image.
- Select the Perceptual or Relative intent as required.
- Tick the Simulate Paper and Ink box as required.
- You can 'Create a Proof Copy' for each ICC profile you use.
- Make adjustments as for Photoshop.

Using a Professional Printing Firm

- Professional printing firms will also have ICC profiles for the printer/paper combinations they use.
- You can install and use these prior to soft proofing in just the same way as for your own printer.
- Set the image size and PPI before saving.
- Ensure that the printers recommended profile is attached to the image before sending it off to be printed.

Perceptual and Relative Intents

- Relative colorimetric maintains a near exact relationship between in gamut colours, even if this clips out of gamut colours.
- Perceptual rendering tries to preserve some relationship between out of gamut colours, even if this results in inaccuracies for in gamut colours.
- Which one to use is image dependent and personal taste.



PPI v DPI

- PPI stands for Pixels Per Inch, i.e. the number of pixels in the image that will fit in one inch on a print.
- PPI has nothing to do with lawyers and annoying adverts!
- Hence if you have an image that is 3000 pixels on one side and you set it so that it prints at 300ppi then the width of the image will be $3000/300 = 10$ inches.
- DPI stands for Dots Per Inch and is related to the spray size of the ink jet and is printer dependent. A printer that prints at 1400dpi will still do so if the image PPI is set to 240, 300 or 600 or anything else.
- For this reason you can forget DPI except when possibly choosing a new printer. On the other hand PPI is important when printing.

Choosing What PPI to Print at

- If you look closely at an image you may be able to see the individual dots that make up the image, but as you get further away the dots merge to form the image.
- Therefore the normal viewing distance for an image dictates the optimum PPI for that image. For small images (e.g. 6x4) 300ppi may be good, but for bill-board posters this may reduce to more like 30ppi.
- For viewing medium size images on a wall typical values may be 180 or 240ppi.
- There is a rule of thumb formula for calculating the optimum PPI to print at which is that the viewing distance is about one to one and a half times the diagonal of the print. Under average viewing conditions PPI approx. equals $1 / (\text{viewing distance} * 0.0003)$ and for optimum conditions it is twice this.
- e.g. an A3 print of 19" x 13" gives a diagonal of 23" which gives a viewing distance of 36". Therefore under average conditions $\text{PPI} = 1 / (36 * 0.0003) = 92$ and under good conditions it is $92 * 2 = 184$.

Summary

- Colour matching between scene and final output will never be perfect.
- A colour calibrated workflow for camera/monitor/printer will reduce the difference.
- ICC profiles can be made under various light conditions for better colour matching.
- Final output should be sRGB for digital image destined for club competitions/the web/other peoples monitors.
- Image sizes for competitions should be within 1400 x 1050 pixels.
- Print output is dependent on the ICC profile used.
- Print size in pixels will depend on the final output size required and the PPI setting.