WHAT IS COLOUR? A SCIENTIFIC PERSPECTIVE

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How do we experience colour? This post will focus on the science of colour – in simple terms and

- **The defining characteristics of colour**
- **How colour is made**
- **How we see and think about colour**

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HOW DO WE EXPERIENCE COLOUR

What is colour? How do we experience colour? This post will focus on the science of colour – in simple terms:

- **The defining characteristics of colour**
- **How colour is made**
- **How we see and think about colour**

The literature on the science of colour and the discovery of how it works is vast! As a result, art books explaining about colour have tended to take one of two paths. They either start with a hefty, very scientific chapter on the science of colour with lots of history, charts and graphs – or they ignore it completely and move straight to explaining the colour wheel.

Either way, I suspect a lot of artists have ducked the science of colour or not had access to the main messages. I've never been great at physics and I've certainly tended to be one of the former in the past! While writing this post, I've also been rather surprised by the number of books which ignore scientific colour basics.

My personal view is that it's very useful for artists to know about some of the basic scientific facts about colour – what it's made up of and how it is created – but that it's probably best to try and avoid a physics lesson!

What I want to do is produce an outline of the science of colour which means that people who want to know more about colour can avoid having incomplete or misconceived notions about colour. In doing so, I'll be focusing on what is known, rather than how it was discovered any by who or exactly how or why it works. So I'm not going to focus on the history of scientific development or the intricacies of the scientific background to the discovery of colour at all!

However for those who do find these things fascinating and/or want to know more after reading this article I've included a number of references to technical articles relating to colour on the internet in a new information site called Colour science, systems and models - Resources for Artists. I've also transferred most of the science references previously on the original information site Colour - Resources for Artists). I can also recommend:

- **Colour** by Edith Anderson Feisner
- **Color – right from the start** by Hilary Page
- **Colour Mixing Bible** by Ian Sidaway

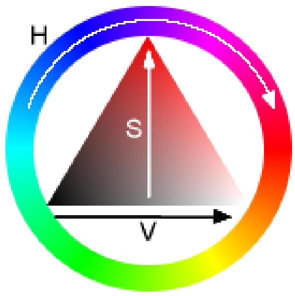
For the rest of us, let's just assume that it's very useful to know about the end result without knowing too much about how it happened - and take the rest on trust!

THE DEFINING CHARACTERISTICS OF COLOUR – HUE, VALUE AND INTENSITY

The most sophisticated machine for differentiating colours is the human eye. But how do we manage to tell one colour is different to another? What makes them different?

Hue, value and intensity are the three essential attributes of perceived colour – the colour we see with our eyes. These are also the defined ways in which the differences in colour can also be described and defined in a scientific way.

These are described below. Other ways of describing colour include local colour and temperature.



These three attributes or characteristics are also known as

- **HSB** (Hue, Saturation, Brightness)
- Digital colour: **HSL** which stands for **h**ue, **s**aturation, **l**ightness, or **HSV** which stands for **h**ue, **s**aturation, **v**alue.
- **Hex Triplets** (for HTML Web colors).

Both hue and value are very important *elements* which contribute to the overall effectivess of any composition.

HUE

Hue is pure colour – one without tint or shade – and is used to describe the actual colour of an object or material.

In everyday use, it's another name for colour as we normally use the word in everyday language. **Local colour** is the term artists use to describe pure colour of a substance which is unaffected by the impact of light.

People have different views about what a colour is. If you asked 20 people to all produce a square coloured red, they'd all produce a slightly different colour of red. Color-Aid papers can be used to identify a hue correctly. Coloured paper was used by Josef Albers when he was developing his ideas about colour.

Primary hues attract the eye. They are easily recognised, stable and offer the greatest degree of contrast.

The hues produced by mixing hues depend on the mixing process used (see How colour is made). I'm going to cover the variety of hues produced through mixing pigments at a later stage.

Pigment/paint manufacturers sometimes use the word 'hue' when they're replaced an original ingredient, which was used as the name for the paint, with a more modern (and often less toxic) substitute which achieves the same hue as the original paint. So for example, a paint may now be known as *Cadmium Yellow (hue)* even though it contains no cadmium.

VALUE

Value - otherwise known as lightness or luminance – is a measure of where a particular colour lies along the lightness–darkness axis. Value measures the impact of light shining (or not) on an object.

Value is also known as the tone (or tonal value). It's often confused with but is not the same as brightness (which is actually about intensity).

Pure hues naturally vary in value and can be found in different places on the value scale. From light to dark they rank as follows: yellow, yellow-orange, orange, yellow-green-yellow, red-orange, yellow-green, green-yellow-green, red, green, red-violet, green-blue-green blue-green, blue-green-blue, blue, violet, blue-violet. To make hues of equal value they need to be adjusted using either white or black.

We name colours as being 'light blue' and 'dark green' but the words we use can be vague and can mean different things to different people. Some scientific colour models have an explicit value as measured by a value scale (see right).

Practical applications of value in art come in Chiaroscuro and Tenebrism which both take advantage of dramatic contrasts of value to heighten drama in art.

INTENSITY

Intensity is also known as **colourfulness** or **saturation** or **chroma**.

A 'saturated colour' is the purity of a hue at its maximum intensity, at its most colourful. Thus, a highly colourful object is vivid and intense. In contrast, a less colourful object appears more muted, closer to gray. With no colourfulness at all, a colour is a "neutral" gray. I tend to think of intensity as being 'in your face' and its opposite as being about 'subtlety'.

More technically,

- *colorfulness* is the difference perceived between the color of an object and gray.
- *saturation* defines the degree of purity of a colour relative to the brightness of a pure hue
- *chroma strength* is a measure of a hue or colour's relative purity or brightness – one to another and compared to white which is the most intense chroma.

Overall Lighter value hues have a stronger chroma than darker value hues. However, in practical and artistic terms, colour lacks intensity when it is painted as a thin wash, as a glaze or is mixed with white to produce a tint.

In plain English, we might call this characteristic a 'shade' when mixing paints. This describes a hue or colour which has been darkened due to the addition of black (or a second colour) or lightened using white.

In printing, **tints** are a range of shades which are expressed as precise percentage values of the hue.

TIP – HOW TO DETECT BRIGHTNESS

You can test which are naturally colourful intense colours by creating a square within a square and then duplicating this. Fill the space between the inner square and the outer square with a uniform neutral grey colour. Then fill the central square with a colour – and repeat for as many number colours as you choose. Then step back and see which hues seem the most colourful – these are the hues which a high degree of natural saturation.

HOW COLOUR IS MADE

The colour that we see is created from light. If there is no light, there is no colour.

The colour that we create on paper or canvas is different and operates in a different way. This is because it's created from pigments or dyes.

THE COLOUR OF LIGHT

Colour is actually a form of energy. The colour that we see is created from light. When light hits a surface, some of the light is reflected and some of it is absorbed. What we actually see is the colour produced by the light waves which are reflected.

Sir Isaac Newton discovered what is called **the visible spectrum of colour**. This is another way of describing the enormous numbers of colours that we recognise. These are all condensed down into all the colours of a rainbow or the coloured light that can sometimes be seen in a prism or a rainbow.

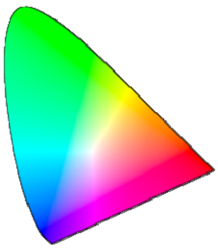
> *spectrum noun (**spectra** or **spectrums**) **1** physics (in full **visible spectrum**) the band of colours (red, orange, yellow, green, blue, indigo and violet) that is produced when white light is split into its constituent wavelengths by passing it through a prism.*
>
> *Chambers Dictionary*

Colour, in very simple terms is created through one of three processes:

- **Additive processing** – which relates to all things visual and digital – which includes everything you are looking at right now).
- **Subtractive processing** – which relates to pigments and paint
- **Partitive processing** – which is based on a viewer's reaction to colour when colours are placed next to one another. This is an important way of understanding colour because the reality is that the norm is that we always see colour in the context of other colours.

Additive, subtractive and partitive processing of colours all produce different results.

ADDITIVE PROCESSING



Additive processing is used for mixing the different colours in light. Mixing colours increases brightness and lightness until it ultimately produces white light. White light is the colour of light at midday. It contains all the wavelengths in the visible range of the spectrum.

Additive processing is responsible for:

- The colour of everything we see
- The presentation of digital colour.

Colour is made up of light waves. The colour that we actually see is what remains when light hits the particular materials in a surface. The light waves associated with that surface are reflected back and the rest are absorbed by the surface. So a pink surface is one which reflects pink light waves and a purple one is one which reflects purple light waves. Black is the colour created when all light waves are absorbed and white is created when all light waves are reflected.

Primary light colours are red, blue and green. More accurately, they are blue-violet, green and orange-red which all combine to make white light. Mixing the lightwaves of these three colours increases brightness and lightness and ultimately produces white light.

The RGB colour model, historically used for cathode ray tube TVs and computer monitors works on the principle of adding together different quantities of red green and blue light.

In simple terms, the human eye can physically see how additive processing works when stage lights with different coloured gels are mixed on one spot on a stage.

SUBTRACTIVE PROCESSING

The subtractive process is used for combining pigments and dyes, paints and printers inks. The bottom line is that mixing colours in a subtractive process absorbs light waves and diminishes lightness.

Primary colours are those which cannot be made by mixing other pigments and are red, blue and yellow. However if all the primaries were mixed together they would create black.

As more and more colours are mixed together they absorb more light waves and reflect less back – until the end result which is black. Although as we all know many of us have been known to take a long diversion making mud colours first!

Subtractive processing is one of the main reasons why artists often talk about trying to achieve 'clean' colours.

PARTITIVE COLOR MIXING

Partitive colour mixing is a perceptual process. The eye creates the colour based on the impression created when one colour is placed next to another colour. This is an important way of understanding colour because in normal circumstances we always see colour in the context of other colours – and in painting we control the process.

Partitive processing is important to painters – because we choose how we place colours on canvas or paper and what we place next to them. If dots of different colours are juxtaposed, your eye performs the mixing process and they can appear to be mixed in an additive process – which increases brightness and lightness. Seurat was famous for painting in dots – called pointillism.

Partitive coloured dot mixing also occurs in colour printing where what is produced is made up of lots and lots of different coloured dots. Thus Pointillism is similar to

- the four-colour CMYK printing process (**c**yan, **m**agenta, **y**ellow, and **k**ey (black) used by some colour printers/presses and
- how pictures on computer monitors and television sets are produced – by using tiny dots of primary red, green, and blue to create colour.

The Munsell Colour system is based on partitive processing and will be discussed later in this project.

TIP – ADJUSTING DIGITAL IMAGES FOR HUE, TINT, SATURATION AND TEMPERATURE

You can change the digital values of images in relation to hue, tint (ie value), saturation (ie intensity) and temperature using Photoshop or PS Elements. You can also see how the lightwave profile of each colour is different.

HOW WE SEE AND THINK ABOUT COLOUR

Our experience is partly down to the physics of how light behaves (see above) and partly down to the physiology of how we physically perceive and register colour. I'm going to focus on two aspects of how we experience colour

- Colour vision - what our eye can see and brain can process
- Colour memory - what our brain can remember

COLOUR VISION – WHAT THE EYE CAN SEE AND THE BRAIN CAN PROCESS

You'll know that vision is a function of both the eye and the brain and colour is perceived using your capacity for colour vision. You can have faults arise in either which can mean that your visual processing of what you can see is less than perfect (e.g. colour blindness). What you may be less clear about is that your vision is also a response to light waves – but you don't need to know how that works – just that it does!

Our capacity to perceive and notice colour is affected by a number of factors which include:

- The level of illumination. For example
  - colours can look very different in different lighting conditions as plein air painters know only too well!
  - In reduced light – red, orange and yellow all appear darker and blue and green appear lighter. Dark-valued pure hues will seem more intense.
  - In strong light – light pure values will seem more intense.
- The nature of the media producing the colour (matte carpet; shiny metal)
- Colours reflected by adjacent objects
- A colour's relationship to other colours present around and about an object
- The way we choose to value a colour or not according to our culture (of which more later).

The combination of eye and brain produces the most sophisticated mechanism known to man for the perception of colour – in theory. In practice, most people probably don't exercise their eyes and brain often enough to reach their full potential

Many a time I've heard painting tutors asking students (and me!) to describe the colour they can see – usually because the way we've represented it on paper is quite a long way from reality. I've learned over time that we can all get much better at both seeing colour and describing colour – but only if we practice! There are some tips at the end.

COLOUR MEMORY – WHAT THE BRAIN CAN REMEMBER

You only need to know one thing. **People tend to have very poor memories for colour**. This is the reason why we have to carry around a piece of curtain fabric or wall paper when trying to match colours when decorating!

For an artist, this means for the artist that unless you have a highly trained colour memory:

- You won't be able to carry the memory of a colour that you've seen in your head for very long. You certainly won't remember all the nuances of colour that you can see.

- It really doesn't matter how many formulae for making colours that you read about, the reality is that you won't be able to remember them.

It's sad – but these are the physiological facts of life when it comes to colour!

What you can do to improve is learn some basic principles which can then be more widely applied – see my tips below.

TIPS - HOW TO IMPROVE YOUR COLOUR VISION AND COLOUR MEMORY

- Believe that light is made of colour. Look for colour in what appears to be darks and lights.
  - Hues exist in every part of the visible spectrum and knowing and believing that fact makes it a lot easier when it comes to seeing what's there. If you believe and think that dark=mud – because of what happens on your palette – then that is what you tend to see. Simple really!
  - I made a huge step forward in seeing colour when a tutor told me to look for blues and violets in shadows and lemons and pinks in lights. It's not that there aren't other colours as well – but being told to look for colours made a difference.
- Learn the basics about how colours mix. For example, know what happens when you mix two complementary colours.
- Make colour studies when painting outdoors to use when painting back in the studio. That way you can potentially have a much better record of the colours that you see than any camera or photograph can ever product.
- Make notes about colours on pencil sketches using words.
  - You can use the names of colours you know well but the words don't have to be 'real colours'.
  - If you don't know the name of a colour or have a fixed idea about what colour a name represents in your mind then you can try another way of describing a colour you know well. For example describe it in terms of items you know well e.g. "My posh frock" or "Gran's bedroom wall". So long as it as meaning for you that's all that counts. You can also have a giggle about what the art historians will have to say in years to come after you've become famous!

APPENDICES

LINKS

- Colour - Resources for Artists
- Colour - Art Book Reviews for Artists
- Colour science, systems and models - Resources for Artists.

GLOSSARY

Additive Processing – This process mixes colour light waves. The more light waves are added the more brightness increases ultimately resulting in the production of white light

Chroma – The greek word for colour. Chroma is defined as a measure of the purity of a hue or its brightness. It also means the difference from gray at a given hue and lightness in the Munsell color system.

Hue – This is pure colour unaffected by light and without tint or shade. A hue is produced by the mixture of wavelengths reflected from the surface of an object. Pure hues naturally vary in value.

Luminescence – see value

Partitive colour processing – This is based on the viewer's reaction to seeing colour next to another colour and is closely related to additive colour mixing. The eye combines dots of different colours which are juxtaposed and performs the mixing process.

Saturation – This defines the degree of purity of a hue i.e. how bright (as opposed to light) it appears or how dull (as opposed to dark) it appears. All pure hues are fully saturated. When no hue is present it has an intensity of zero.

Subtractive Processing – The process of adding pigment colours subtracts light and diminishes brightness. This ultimately results in the production of black when all lightwaves are absorbed.

Value – The lightness or brightness or luminance of a colour. It's a measure of where a particular colour lies along the lightness–darkness axis. Value measures the impact of light shining (or not) on an object.

Visible Spectrum – the band of colours (red, orange, yellow, green, blue, indigo and violet) that is produced when white light is split into its constituent wavelengths e.g. by passing it through a prism or in a rainbow.

BIBLIOGRAPHY

Colour by Edith Anderson Feisner

Colour – Right from the Start by

Colour Mixing Bible by Ian Sidaway

You can find more 'Making A Mark Guides' with advice on sketching, blogging and the art business on the portfolio or publications websites listed on the right.

Portfolio Website:	http://www.pastelsandpencils.com/
Publications Website:	http://www.makingamark.co.uk
Art Blog:	http://makingamark.blogspot.com/
Travel sketchbook blog:	http://travelsketch.blogspot.com