communicating colour

theory
history
vocabulary

sdc
colour
experience

How important is colour?

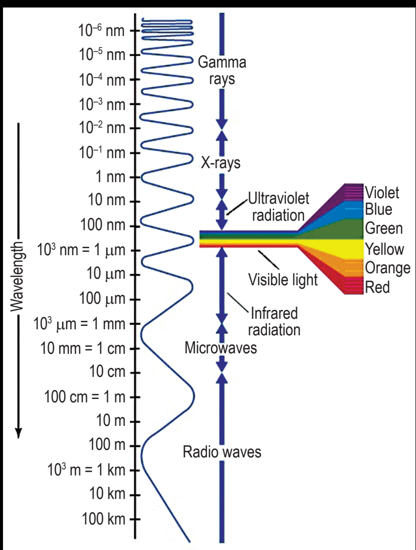
From the moment we open our eyes as tiny babies we are bombarded with colourful images which we take for granted as part of everyday life. Only when colour is removed or changed do we begin to appreciate its significance, note the purple bananas above.

As humans we rely heavily on colour in our visual system. In our early evolutionary development the ability to distinguish between wholesome, healthy food and food that could do harm was frequently reliant on the ability to detect colour changes.

What is colour?

In order to understand more about colour we must begin our journey at the very source with the sun and light.

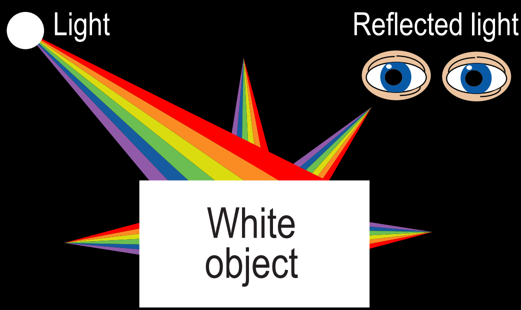
The sun produces an enormous amount of radiant electromagnetic energy. The nature of this energy depends on its wavelength (the difference between two adjacent peaks) of which the effect we know as light is only a tiny part. Other types or radiation include gamma rays and x rays at short wavelengths, microwaves and radio waves at longer wavelengths – none of which are visible.



Light itself is not coloured but when it enters the eye signals are sent to the brain which produce the sensation of colour.

Within the narrow band of visible light the different wavelengths produce the sensation of different colours.

How we see colour

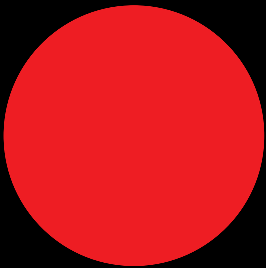


What we call white light is light of all humanly-visible wavelengths. The sensation of white is created by the simultaneous impact of all these wavelengths on the eye.

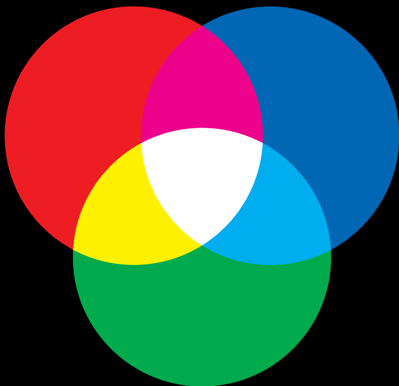
When a rainbow is seen, or white light passes through a prism, the different wavelengths are being separated out so we see them as separate colours.

Just outside our visible spectrum lie areas that are visible to other creatures. Just beyond red lies infra red which we sense as heat, just beyond violet lies ultraviolet (UV) which can damage our skin.

When we look at an object the colour that we see depends on the light that is reflected from it into our eye.



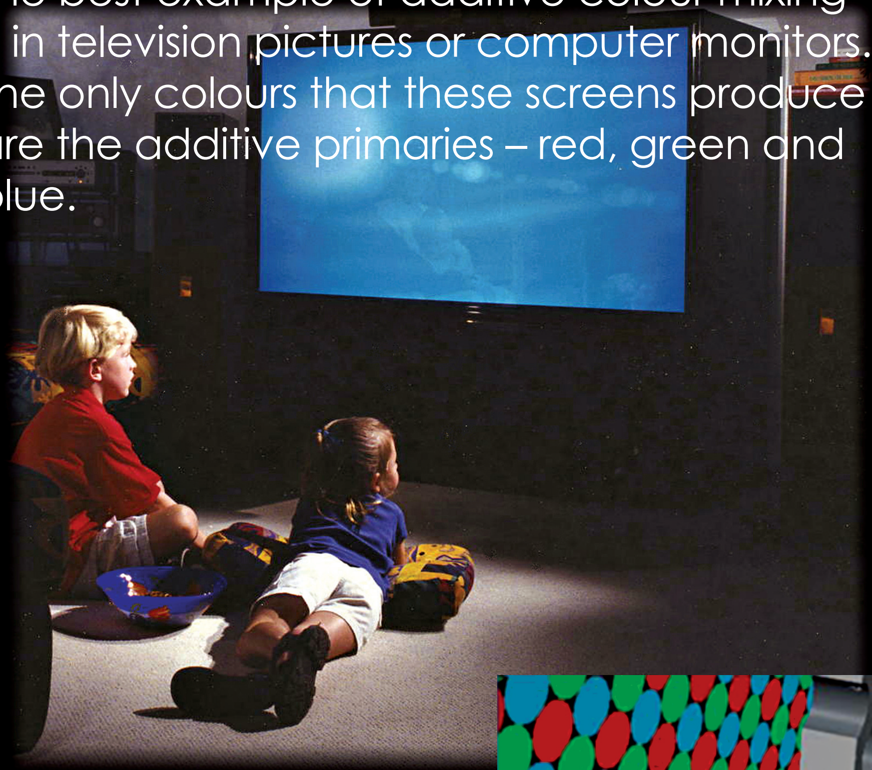
Imagine all the wavelengths (colours) that add together to make white light hitting this dot. Because we see it as a red dot we know the red wavelengths are being reflected into our eyes. All other wavelengths are absorbed by the pigments that make up the dot.



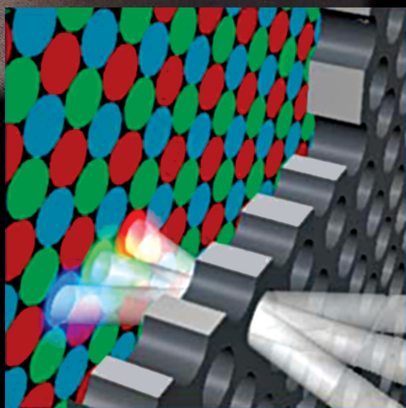
White light can be created by adding together red, green and blue light on a white surface, as depicted in the diagram. These colours are therefore known as the additive primary colours. It can also be seen that three other colours have been created from pairs of the primaries. These colours, magenta, cyan and yellow are additive secondary colours. Remember that here we are mixing light of different wavelengths not paints or inks.

Additive colour mixing in action

The best example of additive colour mixing is in television pictures or computer monitors. The only colours that these screens produce are the additive primaries – red, green and blue.



Each **pixel** on the screen is made up of a red, green and blue light. These can be varied in intensity to produce a clear and detailed image.



On a television, computer monitor or mobile phone screen all the colours visible to us are created by different amounts of red, green and blue light. In theory an infinite number of colours are possible, although the human eye is only capable of distinguishing the difference between 17 million colours across the spectrum.

Our eyes are actually only sensitive to red, green and blue light. Just under 8% of people have problems with detecting one or more of these additive primaries. These people are **colour deficient**, known colloquially as colour blind, although in reality only 1 in 17 million people are totally colour blind.

Important points to note:

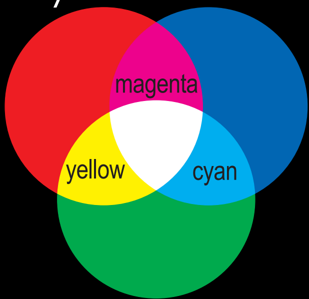
- When the full spectrum shines onto a white surface all the wavelengths (colours) are reflected and we see white.
- When the full spectrum shines onto a black surface all the wavelengths are absorbed and we see black.
- When the full spectrum shines onto a coloured surface some of the wavelengths are absorbed and those that are reflected we see as colour.

Subtractive colour mixing in action

The colours we see in nature and those that are used in paints, inks and dyes are known as subtractive colours because they work by absorbing or taking away some of the wavelengths of the light that shines on them. Pigments and dyes are compounds that absorb light of particular colours extremely efficiently.

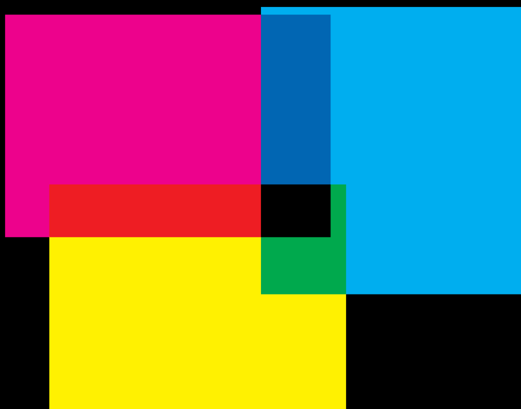
A tomato contains a pigment which absorbs light in the wavelength range from violet through to green, and reflects red through to yellow. This produces the effect of orange-red when it is reflected into the eye.

If a coloured surface absorbs blue light then it will appear as yellow. If it absorbs red it will appear cyan. If it absorbs green it will appear magenta.



These three colours – magenta, cyan and yellow – are known as the subtractive primaries and are the colours that are used daily when painting, printing from a computer or dyeing fabric. From these three primary colours an infinite number of colours can be mixed.

Consider three pieces of overlapping coloured acetate – one of each subtractive



primary (cyan, yellow and magenta). Where they overlap they are taking away progressively more light and producing new, darker colours. Where pairs overlap the three colours produced are the subtractive secondaries – red, blue and green. You may notice that these are the same as the additive primaries. Where all three acetates overlap no light can pass through so we see black.

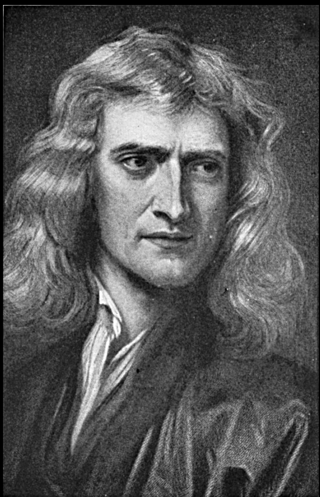
Complementary colours

If we take both the additive and subtractive primaries and form them into a simple colour wheel as below then colours in opposing segments are known as complementary colours.

If we take one such pair of colours, for example blue and yellow, and treat them as colours of light we know from our previous page on additive colours that yellow light consists of a mixture of red and green light. Add these to the colour in the opposite segment – blue – and we have red, green and blue light which we have shown produce white light. This is true for each pair of opposing – complementary – colours.

Historical milestones

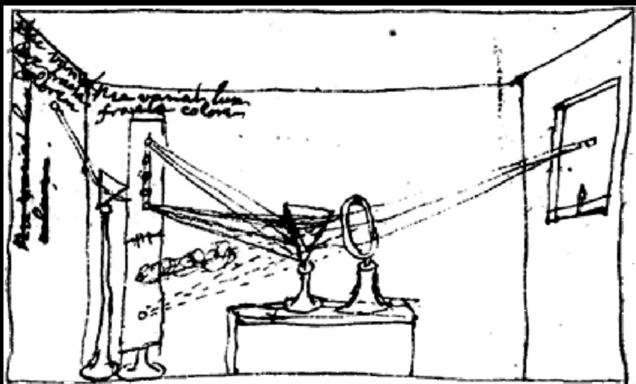
At this point, in order to understand a little more about colour, we need to look back at the way in which various scientists have striven to make sense of the links between light, colour and the way we perceive them.



Much of our understanding of light and colour begins with **Isaac Newton** (1642–1726) and a series of experiments which he published in 1672. He refracted white light using a prism which split it into its component colours of red, orange, yellow, green, blue and violet. In the late 1660s, when Newton began experimenting, people believed that colour was a mixture of light and darkness – red being mostly light through to blue which was mostly darkness – and that prisms coloured the light that shone through them.

His experiment consisted of him setting up a prism near a shuttered window so that a narrow beam of sunlight could pass through.

A beautiful spectrum was projected 22 feet across the room onto the far wall. Further to this he proved that the prism was not colouring the light by using a second prism to recombine the colours back into white light.



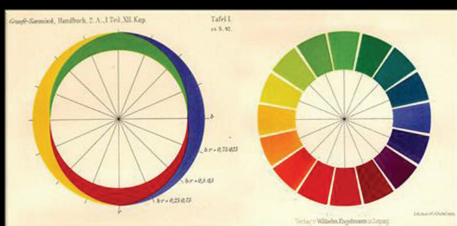
Sketch by Isaac Newton c. 1672

Artists were fascinated by Newton's clear demonstration that light alone was responsible for colour. From an artist's viewpoint the most useful idea was his arrangement of the spectrum colours around the circumference of a circle. This allowed the painter's primaries (red, yellow and blue) to be placed opposite their complementary colours, e.g. red opposite green, as a way of illustrating that each complementary would enhance the other's effect through optical contrast.

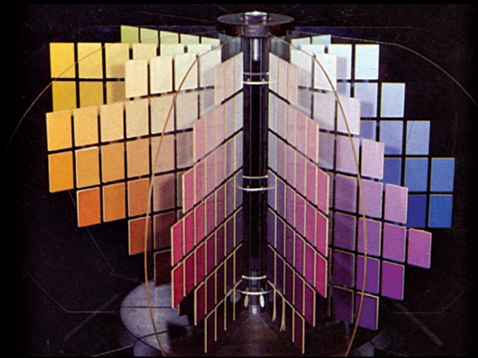
Newton's colour circle became the model for many other colour systems of the 18th and 19th centuries of which Claude Butet's painter's circle of 1708 was probably the first.

Ewald Hering (1834 – 1918) produced a colour circle based on the pairing of opposite colours. He showed how all colours arise from a combination of green-or-red and blue-or-yellow.

The left circle shows the relative mixtures of these opposing colours. The right circle shows what we see when these colours are mixed. The complementary colours are, as in our simpler, modern version, at opposite sides of the circle. This is still a two dimensional colour model.



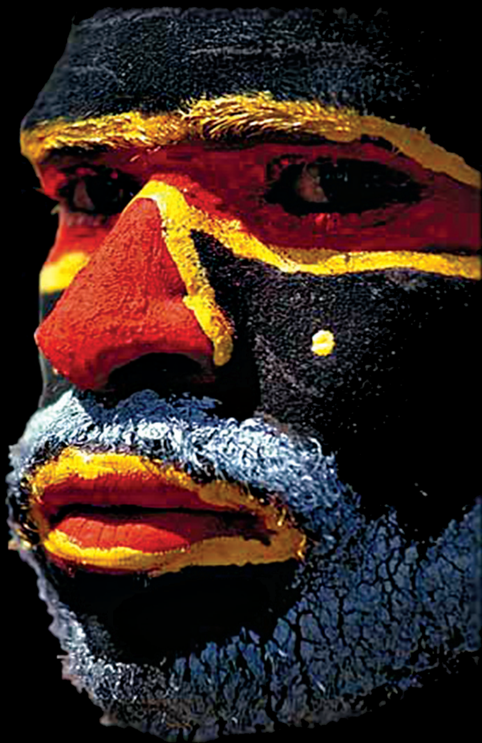
It soon became evident that a two dimensional model was insufficient to fully describe colour. The move into a three dimensional model enabled other colour attributes to be taken into account.



It was **Albert Munsell** (1858–1918), an art teacher, who developed the first widely accepted three dimensional model to help explain colour to his students.

Hue (the basic colour – red, yellow, blue etc.) is represented by the individual leaves of the tree.
Chroma (the strength, weakness or intensity of the colour) is represented by the distance from the centre; increasing intensity away from the centre.
Value (darker or lighter) is represented by the vertical axis; light at the top, dark nearer the base.

The vocabulary of colour



As mentioned earlier, the human eye can discern the difference between 17 million different colours. Of these only a few thousand have been described in the more sophisticated languages. If these descriptions are studied in greater detail it can be seen that even the most complex languages have, in fact, fewer than a dozen words in their colour vocabulary. All other terms are generated by qualifications of a basic word – light blue, dark green, - or by attaching the name of on object or material – violet, orange or ivory – or perhaps joining two basic words together – blue-green. There is one other way and that is by simply plucking a word out of thin air – magenta, for example, is named after the Battle of Magenta in northern Italy in 1859.

Brent Berlin and Paul Kay made an exhaustive study of colour names in 98 different languages and came to the conclusion that basic, universal colour terms do exist. More importantly, it was found that in any language there are never more than eleven basic colour names. They then made the startling discovery that if a language has less than eleven basic colour names then out of 2048 possible combinations of names only 22 were ever used.

In every language studied the colour vocabulary always followed the same simple rules, however primitive or sophisticated the language may be. The rules suggested that languages acquire colour names in a chronological order which could thus be interpreted as a series of evolutionary stages.

The rules appeared to be:

1. No language has only one colour name. They always have at least two. When there are two they are always black and **white**.

2. When there are three names the third is always red.

3. If there are four names then green or yellow are added. If there are five names then green and yellow are added.

4. Where there are six names blue is added.

5. Where there are seven names brown is added.

6. If there are more than seven names purple, pink, orange or grey will be added. These four can occur in any order or combination.

However separated by time and distance, the development of colour vocabulary appears to have followed this same, simple pattern.

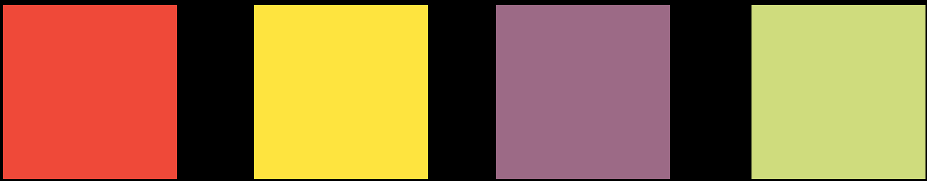
Language of colour

Colour means different things to different people. To a small child colour is a wonderful, exciting adventure with paints and crayons while an adult working in a dyeworks or paint factory would see colour as a recipe or formula.

To understand this complicated world of colour it helps to separate it into a number of different ways of identifying colour.

Everyday name: our first experience of colour as a descriptive and communicative tool. These are words such as red, purple, yellow.

Marketing name: the huge range of colours that are available today as paints, inks or dyes cannot be described in terms of everyday colours so new descriptive names are created to help marketing.



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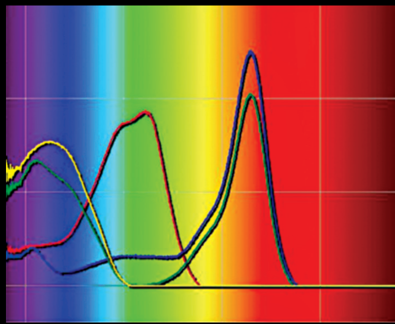
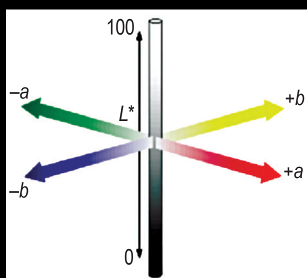
Colour recipe: if a marketing or everyday colour is to be produced it must be described by a formula or recipe. This will be used by an operator in a dyeworks or paint manufacturers or even a d.i.y. store to enable them to mix a particular colour. Formula colours are also used to produce a given result in the printing industry. The proportions of the subtractive primaries (cyan, magenta, yellow – CMY) and black (K) have to follow a given formula. Also a formula is used to establish the relative outputs of the red, green and blue additive primaries (referred to as RGB) to produce a given result on a TV screen.

Measured colour: a coloured surface absorbs and reflects different wavelengths of light. The reflected wavelengths can be measured by a spectrophotometer. The spectrophotometer is a powerful electronic eye. A coloured object is illuminated by a known light source and the reflected light is collected and separated into each individual wavelength. This information is presented in the form of a graph known as spectral data or a reflectance curve.



This method of describing colour would be used by dyers and colourists to ensure consistency in colour matching etc.

Coded colour: both the following examples are ways in which physically controlled systems are used along with the human eye to identify colour and provide a structure for colour matching.



a) chromaticity is a method of describing colour using additive colour mixing to produce a colour match with a given sample. The colour is described in terms of its hue and chroma.

b) physical colour is probably the easiest method of colour matching and recording to understand. It is used in the Natural Color System (NCS), the Dulux Colour Specifier and the Pantone colour system.

From thousands of colour swatches it is simply a matter of finding the nearest match to the sample. This will identify the sample with a code which will be recognised internationally. Sampling should always be done under controlled lighting conditions.

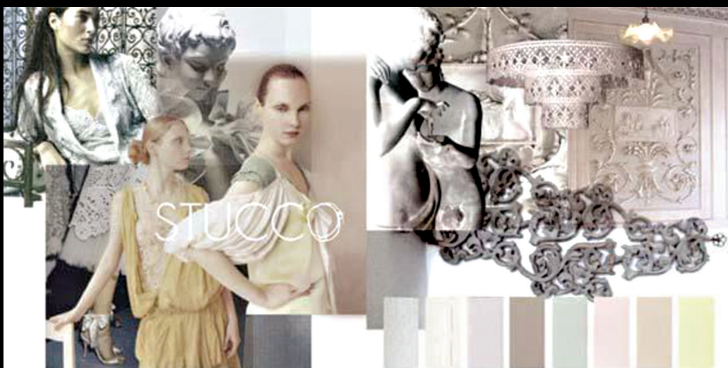
We have so far identified six different ways of describing colour. Each has developed to serve a different need.

However there is one more important aspect to consider and that is the way in which our perception of colour is affected by changes in light, texture, reflectance and the anomalies created by the human eye and brain. This we can call **perceived colour**.

This can be illustrated by looking at the small piece of carpet above. The red is perceived to be a totally different colour where it is surrounded by a blue line compared with the area where it is surrounded by green. The red is exactly the same in both areas but is perceived to be different. This effect is due to **simultaneous contrast**. More information about this can be found in our booklet entitled *Visual Perception and Other Phenomena*.

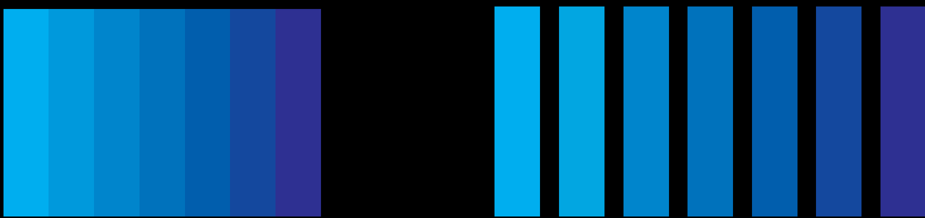
Colour and design

For most people, and particularly designers, it is colour as a visual experience that really matters. It is the way colours appear that conveys meaning and stirs emotions. This being the case it is most helpful for designers to be able to work with a colour system such as the NCS where the colour matching is based on the designer's perception of a colour rather than on a mechanical operation.



Designers also need to be able to work with other kinds of colour. They work with paints, inks and dyes which are formula colours. They work with computers and send files to be printed which is, again, formula colour. Another application of formula colour will be experienced when using a colour matching system such as Pantone.

Designers are able to see how a particular recipe of inks or dyes will appear when printed or dyed. However a given mixture will not always look the same. This may be due to changing light conditions, the effect of simultaneous contrast or some other visual



Where strips of similar plain, flat, colours are placed next to each other our perception is of strips that are shaded, creating a fluted appearance. This is known as the Mach band effect.

Rather than calling this an illusion it is more useful to recognise that colour in its physical form, as a dye, ink or paint is one thing and colour as a visual experience in context is something totally different.

When designers work with inks, paints or dyes they are manipulating physical substances to achieve particular appearances.

Understanding that the appearance of a substance will be altered by the context in which it is seen will help designers avoid mistakes and will allow them to use the knowledge to their advantage.




From the birth of the solar system the sun's energy has contained the coded information that millions of years ago allowed our earliest ancestors to experience colour as a tool for survival.

It is through necessity that we have acquired the ability to distinguish the millions of colours that we see each time we open our eyes.

It is a never ending challenge to understand and control the complex and wondrous world of colour that we perceive each day and in our dreams at night.

We have developed a complex language, tools and materials to enhance our understanding and ability to control this experience which most of the world takes for granted.

Humans are still expanding their knowledge of colour and have only scratched the surface of its complexity and diversity.

We hope this booklet will give some insight into the fascinating and amazing world of colour.

Sponsorship of this booklet is in remembrance of Derek Moorhouse, whose work in textiles and colour was an inspiration to others. May this booklet encourage you to achieve your full potential. The rest of your life is in front of you – make the most of your opportunities.

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