The Reign of Light
(unpublished)

When J. M. W. Turner painted the inelegantly titled *Light and Colour (Goethe's Theory) – The Morning After the Deluge* around 1843, he gave us a work more modern than anyone could then have anticipated. Many of his contemporaries were utterly at sea with this almost abstract swirl of glowing primaries; even before Turner had so thoroughly shed the trappings of representational landscape, his critics derided his sun-drenched veils of mist as 'pictures of nothing, and very like'. But in his abandonment of line and his embracing of colour and light as the key elements of art, Turner does not look old-fashioned next to the luminous colour fields of Mark Rothko or the golden veils of Morris Louis.

Turner's *Light and Colour* advertises its debt to Goethe's *Theory of Colour*, published in 1810 and read by the British artist after the book's translation into English in 1840. Goethe's ideas on colour, a curious mix of anti-Newtonian polemic, dogmatic mysticism and useful insight, exerted a powerful pull on several artists into the early twentieth century, such as Kandinsky and Mondrian. But Turner's other debt is unannounced, yet unmistakable. His colours themselves, blazing in primary hues that defied convention, are largely the product of nineteenth-century chemistry, and without them Turner could never have so vividly outshone his contemporaries.

Several years later, this new palette—to which chemists were ever adding more bright materials—set on fire the paintings of the Pre-Raphaelites. But it was when they reached the hands of the Impressionists in the 1870s that the nineteenth-century innovations in colour really began to challenge the painter to transform matter, squeezed from a tube, into an image of radiant light.

The French symbolist poet Jules Laforgue, more perceptive than many of his coeval art critics, saw what these artists were after:

> In a landscape flooded with light… the Impressionist sees light as bathing everything not with a dead whiteness, but rather with a thousand vibrant struggling colours of rich prismatic composition… The Impressionist sees and renders nature as it is – that is, wholly in the vibration of colour.

Others saw it differently. The critic E. Cardon said sarcastically of the first Impressionist exhibition in 1874, 'Soil three quarters of a canvas with black and white, rub the rest with yellow, distribute haphazardly some red and blue spots, and you'll obtain an impression of spring in front of which the adepts will be carried away by ecstasy.' When the group staged a second exhibition two years later, it elicited similar complaints: 'Try to make M. Pissarro understand that trees are not violet, that the sky is not the colour of fresh butter'.

The dividing factor, it seemed, was colour. In the early nineteenth century, painting had become a discipline constrained by rigid conventions. The French Academy of Fine Arts had long decided that skill at drawing—the use of line to produce a 'noble contour'—was the artist's most important attribute, and that colour was of secondary importance. So

students at the Ecole des Beaux-Arts in Paris were lucky if they ever got to hold a paint brush, rather than a pencil. They were expected to learn how to execute a painting in a style that erased all visible signs of effort, so that the surface was smooth and glossy and devoid of all brush marks. This was the style championed by the haughty academician J.-A.-D. Ingres.

And as far as colour was concerned, the role models were painters like Poussin and Watteau, whose palettes were sombre. Artists were expected to convert the vibrant greens of nature into low-keyed browns. Sir George Beaumont, patron of John Constable, summed up the colour sensibilities of the age: 'A good picture, like a good fiddle, should be brown.'

These stifling traditions were, however, challenged on both sides of the English Channel: in England by Turner, in France by Eugene Delacroix, whose energetic brush work and bright colours made him seem, to the academicians, a danger to art. Delacroix ridiculed the colour use of the school of Jacques Louis David, who taught Ingres. They imagined, he said,

> that they could produce the tones Rubens got with frank and vivid colours such as bright green, ultramarine etc., by means of black and white to make blue, black and yellow to make green, red ochre and black to make violet, and so on… if the picture be placed near a richly coloured work such as a Titian or a Rubens, it appears what it really is: earthy, dull, and lifeless.

When the Impressionists began to win the public's attention (if not acclaim) in the 1870s, they had a new set of 'frank and vivid' colours, brighter than any had seen before. And they looked to Delacroix for inspiration as to how to use them. Where had these colours come from?

Accident and industry

Prussian blue, discovered in 1704 or 1705, is generally regarded as the first of the 'modern' colours. But in truth it is something of an anomaly, appearing well before the blossoming of chemistry as a science in the late eighteenth century. Like so many other innovations in colour, it was the result of a serendipitous accident.

At this time the manufacture of pigments for artists was barely industrialized. In the Middle Ages and the Renaissance, painters got their pigments from apothecaries and pharmacies, who made them by the methods of 'alchemy'. This kind of small-scale operation was still being conducted in the 1700s, when indeed alchemy itself was by no means extinct. A Berlin-based colour maker called Diesbach was working in the laboratory of the alchemist Johann Konrad Dippel, and in the course of preparing a red lake pigment Diesbach asked Dippel for some potash (a potassium alkali).

Presumably to economize, Diesbach requested a batch of potash contaminated with oils prepared from animal blood. It was a false economy, for his pigment turned out very pale. Attempting to concentrate it, he succeeded instead in turning it deep blue. He had no idea

what had transpired, but was astute enough to recognize the blue material as a potential pigment in its own right, and was soon manufacturing it according to a jealously guarded recipe.

Prussian blue, which is iron ferricyanide, became popular throughout Europe by the mid-eighteenth century, after an Englishman named John Woodward discovered and published an (unnecessarily elaborate) account of its synthesis in 1724. It was particularly valued for mixing light blues, and appears in skies by Watteau, Canaletto and Gainsborough (where it has tended to fade).

It was in the 1770s, however, that the real era of pigment innovation began. In 1775 the Swedish apothecarist Carl Wilhelm Scheele, one of the finest experimental chemists of his age, discovered a bright green compound of arsenic: copper arsenite. This reached artists' palettes as Scheele's green—until it was largely superceded by a new arsenic-based green devised in 1814 in Germany, which the English called emerald green. Both these new greens were relatively cheap and were used as household paints. Not until the mid-nineteenth century were the attendant health risks of these arsenic-laced colours recognized; it is claimed, albeit speculatively, that Napoleon's death in exile on St Helena was hastened by dust or fumes from his green wallpaper.

Industrial manufacturing processes have long been a fertile hunting ground for new materials and methods for artists' pigments. Zinc smelting grew in importance during the nineteenth century, and helped to secure the rise of zinc white as a replacement for the centuries-old lead white, the production of which created illness and deaths through lead poisoning. And in 1817 the German chemist Friedrich Stromeyer identified a new element, cadmium, as a by-product of zinc refining. He found that cadmium combines with sulphur to make strong yellow and orange compounds, which were marketed to artists from the 1820s as cadmium yellow and cadmium orange. In the early twentieth century a deep red version was manufactured too, in which some of the sulphur was replaced with selenium. Cadmium red was a favourite pigment of Matisse—who knew a thing or two about red, as his *Red Studio* (1911) testifies.

But perhaps the most versatile metals for expanding the artist's rainbow were cobalt and chromium. Cobalt minerals have been used in blue pottery glazes for millennia, and cobalt is also the colouring agent of the pigment called smalt, used since the Renaissance. But smalt is a rather crude blue, and difficult to work with as a material. When the French government set Louis-Jacques Thénard the task of devising a synthetic alternative to expensive and rare ultramarine at the beginning of the nineteenth century, he found inspiration in the cobalt blue glazes of the potters at Sevres.

This trail led Thénard to the modern pigment known as cobalt blue: cobalt aluminate. It is a fine, pure blue, and was widely used by the Impressionists. The strong blue waters in Renoir's *Boating on the Seine* (1879-80), for instance, are rendered in this colour, used in some places straight from the tube. Cobalt also furnished a sky-blue pigment—cerulean blue, which is cobalt stannate—as well as a yellow, aureolin, and the first pure purple

pigment ever known, cobalt violet. Previously, artists had always had to make purples by mixing blue and red.

Chromium was the chameleon-like fruit of a Siberian mineral, called crocoite and discovered in the eighteenth century. The mineral is deep orange, a natural form of lead chromate. It was analysed in the late 1790s by the eminent French chemist Nicolas Louis Vauquelin, who identified the new element chromium as the source of the colour. Vauquelin studied the compounds of chromium, and found that he could make bright yellow and rich orange versions of lead chromate, both of which he proposed as potential pigments. Chrome orange became the first pure orange pigment since the medieval use of realgar, a highly toxic compound of arsenic. The chromium colours did not become widespread, however, until the discovery of chromium-containing mineral deposits in France, USA and Britain.

By replacing the lead in chrome yellow with other metals, such as zinc and strontium, the colour could be tuned to paler or more acidic hues, such as 'lemon yellow'. And Vauquelin also commented on '*un vert extrememement beau*' made by roasting crocoite to form chromium oxide. In 1838 this was modified (by incorporating water in the crystals) to make the vibrant green called viridian, a colour that became almost emblematic of Paul Cézanne.

The craft of dyeing has always been a rich source of artist's colours. The blue dye indigo, an extract of a pea plant native to Asia, was used to colour the shields of the Roman army, and was a cheap alternative to expensive mineral blues for Renaissance painters. Red lake pigments are prepared by affixing the red colourants of the dyers, such as lac (a resin exuded by tree-dwelling insects), cochineal (squeezed from beetles native to Eastern Europe and the New World) and madder root, to the surface of a white mineral powder such as alumina. But in the mid-nineteenth century, synthetic chemistry began to generate artificial dyes far more lurid than these natural ones.

The first of the synthetic dyes to have a commercial impact was aniline purple, or mauve, made from organic (carbon-based) compounds extracted from coal tar, the black sticky residue of gas-lamp burning. Mauve was made accidentally in 1856 by William Perkin, a young student at the Royal College of Chemistry in London, during experiments that were supposed instead to yield the anti-malarial drug quinine.

Other aniline colours soon followed: magenta, blues, reds. Chemists figured out how to make synthetic alizarin, the red colourant of madder, and artificial indigo; and they created new classes of synthetic dyes, such as pinkish eosin and yellow azo dyes. Some of these found their way onto the artists' palettes. But many of the new dyes faded rapidly in light, and in 1897 the French artist and academician Jean-Georges Vibert denounced them as a 'catastrophe for painting'. Van Gogh was amongst those who experimented, to his cost, with the fugitive eosin-based pigments.

The banishment of earth

Armed with this new battery of brilliant colours, the Impressionists set their canvases alight with fireworks, leading the conservative Vibert to denounce them as 'dazzlers' (*éclatistes*) who painted 'only with intense colours'. Pissarro claimed to have banished the old, dull 'earth' colours from his palette, and Monet constructed his ochres and khakis from complex mixtures of the new, bright pigments. Even the gloom of Monet's *La Gare Saint-Lazare* (1877) is a concoction of rainbow hues: cobalt blue, cerulean blue, synthetic ultramarine (made since 1828), emerald green, viridian.

The Impressionists rejected both white and black: 'White does not exist in nature', said Renoir, and 'Shadows are not black'. To him and especially to Monet, shadows were instead typically violet, the complementary colour to yellow sunshine. 'I have finally discovered the true colour of the atmosphere', said Monet. 'It's violet. Fresh air is violet. Three years from now everyone will work in violet.' The Impressionist love of this shade led even the favourably disposed critic Joris-Karl Huysmans to accuse them of 'indigomania', as if it were some genuine collective disease.

Thus the typical Impressionist palette shines with strong colours, most of them inventions of the nineteenth century. These were the colours that inspired Vincent van Gogh to abandon his earlier, dull hues when he came to Paris and to take up high-keyed colours that became indispensible tools for constructing his passionate visions. 'Cobalt [blue] is a divine colour', he declared to his brother Theo, 'and there is nothing so beautiful for putting atmosphere around things… The same with emerald green. It is bad economy not to use these colours, the same with cadmium.' Matisse, a pupil of Pissarro, took things further, bringing Post-Impressionist colour to a new pitch in the Fauvist movement of 1904-7 before embarking on a quest into the constructive possibilities of colour that prefigured the whole of twentieth-century painting. According to Picasso,

> If all the great colourist painters of this century could have composed a banner that comprised each one's favourite colours, the result would certainly have been a Matisse.

That banner would hang in commemoration not only of one of art's greatest colourists but of the ability of chemistry to bring colour into the world.

Philip Ball's book *Bright Earth: Art and the Invention of Colour* will be published in early 2002 by Farrar, Straus & Giroux/Penguin.