The making of Cézanne's palette
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Innovation in art has always been a gamble. While originality may be given lip-serving credit, unfamiliarity has an even chance of breeding contempt. There is no other word to describe the critics' response to the first independent exhibition by the Impressionists in Paris in 1874. These artists, it was claimed, had rejected "good artistic manners, devotion to form, and respect for the masters". Part of the outrage was directed at the choice of subject—ordinary people going about their business, for goodness' sake—and part at the quick-fire style of the brush strokes. But the detractors were also offended by the colours.

The critic E. Cardon said sarcastically, "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." The second group exhibition two years later elicited similar complaints: "Try to make M. Pissarro understand that trees are not violet, that the sky is not the colour of fresh butter...". Renoir's "green and violet spots" in areas of flesh were seen to "denote the state of complete putrefaction of a corpse".

Yet these were not new charges. In England, the Pre-Raphaelite painters such as William Holman Hunt and John Millais stood accused in the 1850s of using greens "unripe enough to cause indigestion". J. M. W. Turner, the supreme British colourist of the early nineteenth century, had in 1829 been denounced for producing "a specimen of colouring run mad" in his *Ulysses Deriding Polyphemus* (Figure 1).

What was striking, and to some eyes offensive, about the works of all these artists was that they were using colours never before seen on canvas. Bold use of colour was not in itself a revelation—Titian and Rubens were amongst those who had delighted in it in previous times. But these new colours were different from the red lakes, the Naples yellow and the ultramarine of the Old Masters. They were the products of the Golden Age of chemistry. More than in any earlier age, chemistry had become the handmaid to the arts.

Art in the second half of the nineteenth century was totally transformed by such developments in practical science, and this influence was felt throughout the modern era. Paul Cézanne and Henri Matisse both began their careers as Impressionists, steeped in the new colours. Matisse brought out their full potential as the leading light in the movement known as Fauvism, which brought brightness to a new pitch (Figure 2). Along with Picasso, these two artists are considered by critic Robert Hughes to be the most important of the twentieth century. Picasso himself said:

> 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.

One might imagine, in view of all this, that an appreciation of the painter's sources of colour would be essential to understanding Western art. But this has scarcely been deemed the case. Art historian John Gage confesses that "One of the least studied aspects of the history of art is art's tools". Anthea Callen, a specialist on the techniques of the Impressionists, makes a stronger criticism:

> Ironically, people who write on art frequently overlook the practical side of their craft, often concentrating solely on stylistic, literary or formal qualities in their discussion of painting. As a result, unnecessary errors and misunderstandings have grown up in art history, only to be reiterated by succeeding generations of writers. Any work of art is determined first and foremost by the materials available to the artist, and by the artist's ability to manipulate those materials. Thus only when the limitations imposed by artists' materials and social conditions are taken fully into account can aesthetic preoccupations, and the place of art in history, be adequately understood.

So just how did the nineteenth-century iconoclasts obtain their materials? Where did these bright new colours come from?

Making colour

Paints are a combination of two main elements: a colouring material (generally a powdered pigment) and a clear, liquid binding medium. Between the demise of the "egg tempera" technique favoured by medieval panel painters, in which egg yolk was used as the binder, and the introduction of modern synthetic resins and solvents in the twentieth century, most serious artists used oils as the binding medium. Many of the oldest pigments are either ground-up minerals, such as the iron oxide ochres, or inorganic solids manufactured by primitive chemical technology. Vermilion, for instance—the most prized red of the Middle Ages—is mercury sulphide, made by alchemists from pure sulphur and mercury.

Nature provides few brightly coloured substances suitable for use as pigments—the green copper mineral malachite, for example, and the closely related blue copper salt azurite. Most richly coloured pigments were therefore synthetic. Even in ancient Egypt, chemical technology was sophisticated enough to make a variety of strongly coloured compounds, such as lead antimoniate, later called Naples yellow, and lead tetroxide or "red lead".

This palette was supplemented little by little throughout the ensuing centuries—several innovations in the late Middle Ages, such as the preparation of ultramarine and red lake pigments, helped to fuel the explosion of colour evident in Renaissance art. But by the eighteenth century, artists were still lacking reliable, bright materials for many basic colours. Their greens were never really bright enough, and were usually made instead by mixing blues and yellows. There was no pure orange pigment aside from the deadly poisonous realgar (arsenic sulphide). Blues were either expensive, such as ultramarine and azurite, or slightly dull, such as the organic dye indigo. The yellows had a slightly dull edge too, or were liable to fade (if prepared as lake pigments from vegetable dyes). There was no pure purple pigment at all.

Artists felt these gaps keenly. In the 1670s the Dutch painter Samuel van Hoogstraten lamented "I wish that we had a green pigment as good as a red or yellow. Green earth is too weak, Spanish green [verdigris] too crude and ashes [green verditer, a copper carbonate] not sufficiently durable." The Spanish artist Diego Velazquez seems to have concurred with these complaints: he never used a pure green pigment in his life, but always mixed them from azurite and yellow ochre or lead-tin yellow. Even that was not necessarily an improvement: in his painter's handbook of 1758, Robert Dossie says that "the greens we are forced at present to compound from blue and yellow are seldom secure from flying or changing."

For blues, indigo was for centuries the only alternative with a depth of tone comparable to ultramarine. Yet it is a poor substitute: it has a greenish tinge that compares ill with ultramarine's gorgeous purple, and it tends to fade when exposed to light. When the pigment Prussian blue was discovered in the early eighteenth century, the first report describing it begins thus: "Painters who mix oil with their colours have few that represent blue, and those such that, rightly, they wish for [some] more satisfactory."

Prussian blue (iron ferricyanide) is often cited as heralding the new age of synthetic pigments. It was discovered by accident in 1704 by a Berlin-based colour maker, and the convoluted method of its making (involving animal blood) was kept a jealously guarded secret until 1724, when an Englishman named John Woodward acquired and published a description of the process. Prussian blue was claimed to give a colour "equal to or excelling Ultramarine". But Dossie reported that the lighter, brighter and most attractive varieties of Prussian blue were "extremely subject to fly, or to turn to a greyish green". This has made the skies in several painting by Gainsborough, Watteau and Canaletto pearly and washed out where once they would have been a deeper blue.

The pursuit of brightness

By the end of the eighteenth century, chemistry had finally acquired a consistent conceptual system: Antoine Lavoisier's oxygen theory of combustion, which replaced the last vestiges of alchemy embodies in the phlogiston theory. Lavoisier's new chemistry, laid out in his *Traité Élémentaire de Chimie* (1789), became the norm in France, and was energetically advocated in Germany by Martin Klaproth. (England was slower to acquiesce to the Gallic system.) Lavoisier secured the ascendancy of his ideas by renaming the entire system of elements in accordance with it, in *Méthode de Nomenclature Chimique* (1787) written with fellow chemists Bernard Guyton de Morveau, Claude Louis Berthollet and Antoine François Fourcroy. Even after Lavoisier's execution in 1794, this group dominated French chemistry and helped to make France the world leader in the subject.

It was an era of chemical discovery. Lavoisier's *Traité Élémentaire* lists 33 elements; between 1790 and 1848, 29 more were added to the list. Not only had chemistry a new vocabulary; it had developed a powerful set of experimental techniques for analysing substances into their basic components. One of the finest experimentalists of the age was the Swedish apothecarist Carl Wilhelm Scheele, who was one of the first to isolate (though not to identify) oxygen gas—he called it "fire air". Scheele also discovered chlorine and barium, and in 1775, while experimenting on arsenic compounds, he isolated a bright green compound. This was copper arsenite, which soon became used as a green artist's pigment called Scheele's green.

In 1814 a new arsenic-based green pigment was discovered by two German chemists working in the town of Schweinfurt. This became known in England as emerald green, and for a time it was the finest green pigment known, rapidly displacing Scheele's green. Unfortunately, however, it was also poisonous, and if exposed to dampness it decomposed into arsine, a toxic gas. Because it was quite cheap to manufacture, emerald green was used not only as an artist's paint but as a household paint: it was widely used on patterned wallpaper. This made damp rooms death traps, and in the 1860s the British *Times* newspaper expressed alarm about the possibility that young children were being killed by the deadly fumes emanating from their bedroom walls. It is believed that Napoleon's death in exile on St Helena was hastened this way.

Perhaps the most important innovations in artists' colours in the nineteenth century stemmed from the discovery in the late eighteenth century of a bright red mineral from Siberia, called crocoite or Siberian red lead. In 1797 the French chemist Nicolas Louis Vauquelin, a colleague of Fourcroy, began to investigate crocoite and discovered that it contained a new metallic element whose compounds were brightly coloured. For this reason he proposed the name *chrome*, from the Greek word for colour. We now know it as chromium.

Crocoite is a mineral form of lead chromate. Vauquelin was able to make this compound synthetically in pure form, and he found it had a bright yellow colour. He and Berthollet proposed in 1804 that it be used as a pigment; and by 1810 Thomas Lawrence in England was already using this "chrome yellow" in his *Portrait of a Gentleman*. Various other metal chromates offered fine distinctions between yellows: the pigment known commonly as "lemon yellow" could consist of barium chromate, strontium chromate, or a mixture of lead chromate with lead sulphate. Zinc chromate, or "zinc yellow", became an important commercial pigment because of its rust-preventing properties, and was later used on military equipment during the Second World War.

Vauquelin found he could also make a different form of lead chromate that was orange—the first pure orange pigment since hazardous realgar. And chromium oxide was a green colour, which became marketed as a rich green pigment called viridian in England. (The French knew it as *vert émeraude*, tempting confusion with the chemically distinct "emerald green" in England.)

In the first few decades of the nineteenth century the new pigments just kept on coming. In 1817 a German chemist called Friedrich Stromeyer found that a new element called cadmium, a by-product of zinc smelting, could be combined with sulphur to make bright yellow and orange pigments called cadmium yellow and cadmium orange. In the early twentieth century a reliable method was found for manufacturing a red version too, and cadmium red became a tremendously popular pigment, much favoured by Matisse.

The French government recognized at an early stage that pigment manufacture could become an important stimulus to French industry, and appointed leading chemists to devise new colours. Guyton de Morveau proposed in 1782 that zinc oxide replace lead white as a white pigment, since the manufacture of the lead pigment was known to produce lead poisoning amongst workers. But it took over 50 years before a practical means of manufacturing zinc white became available.

The Minister of the Interior at the end of the eighteenth century, Jean-Antoine Chaptal, was himself an eminent chemist, and he charged Louis-Jacques Thénard, a protégé of Vauquelin, with the task of making a synthetic substitute for expensive ultramarine. In 1802, Thénard found a way to make a rich blue colour from cobalt, which became known as cobalt blue. Greenish blue cobalt stannate, known as cerulean blue, became available around 1860, and was used by the Neo-Impressionist painter Paul Signac. In the 1850s a cobalt-based yellow pigment called aureolin became available in France, closely followed by a purple cobalt pigment called cobalt violet, the first ever pure purple pigment.

What painters really wanted for a blue, however, was a cheaper form of real ultramarine. In 1824 the French Societé d'Encouragement pour l'Industrie Nationale offered a prize of 6000 francs for the first practical synthesis of ultramarine itself. It is a complicated compound to make—an aluminosilicate in which the blue colour comes not from a metal but from the presence of sulphur. In 1828, a Frenchman named Jean Baptiste Guimet claimed the prize, although the German pigment manufacturer Christian Gmelin immediately argued that he had done it first. The French decided, probably more from patriotism than anything else, to uphold Guimet's claim.

A new aesthetic

Pigment manufacture was now big business. Factories were set up in the nineteenth century to make and grind pigments. Some sold them in pure form to the artist's suppliers, who would then often mix up the paints for their customers from pigment and oil. But some pigment manufacturers did it all, making the pigments and mixing them into ready-made oil paints which, from the 1840s, were sold in collapsible tin tubes.

What this meant was that painters became ever less familiar with what it was they were buying, and had no way of assessing the quality of the new paints they were being offered. A new breed of professional began to appear: the colourman, who had some degree of chemical knowledge that allowed him to test the materials he provided to artists. It became essential for painters to cultivate a good relationship with a reliable colour merchant. In Paris, Camille Pissarro, Paul Cézanne and Vincent van Gogh used the services of Julien Tanguy, who ran a small shop in Montmartre from 1874. Van Gogh twice painted the merchant's portrait, despite complaining on several occasions about his wares. Tanguy ground his own colours, and one of the advantages for the artist of such a supplier was that he could provide materials tailored to order.

In England, the foremost colourman of the nineteenth century was George Field, who supplied paints to Constable, Lawrence, Turner and the Pre-Raphaelites. These painters relied on Field's judgement as to whether or not a colour was reliable—whether, for example, it would rapidly fade or discolour on the canvas. Field's treatise on the chemistry and properties of pigments, *Chromatography* (1835), was highly influential amongst British artists.

Thanks to Field, Turner was able to acquire the new colours almost as soon as they were invented, and he was amongst the first painters in England to use cobalt blue, emerald green, viridian, chrome yellow and others. This was a gamble, even with Field's assistance, since some colours might lose their brilliance over a matter of several years. Some of Turner's works have suffered from this lack of stability of the colours.

Turner's use of colour was an important influence on the Impressionists such as Monet, who came to London to see his work. The Impressionists themselves made equally avid use of the new colours, and preferred to use them directly from the tube. In *Boating on the Seine* (1879-80) by Pierre-Auguste Renoir (Figure 3) there are just seven pigments apart from the traditional lead white, and all but the reds are "modern" synthetic colours: cobalt blue, viridian, chrome yellow, "lemon yellow" and chrome orange. They are applied almost unmixed, and the impact of the new pure orange is very apparent in the boat's outline. The river is portrayed in cobalt blue, with a little white added in places and with a glaze of red lake to produce the purple shadows. This is Impressionism straight from the tube.

Claude Monet was so enamoured of the new bright colours that he insisted on mixing even his dull tones from these strident pigments. In *Lavacourt under Snow* (c. 1879) (Figure 4) the subdued tones in the cottages, the trees and the pale yellowish sky are not rendered in ochres or earth pigments but are mixed from bright hues: cobalt blue, viridian, cadmium yellow, vermilion. With viridian, emerald green, synthetic ultramarine, red lake and lead white, these make up the entirety of the palette. The blue field of snow is pure cobalt blue in its brightest places, mixed only with white.

The Impressionists shaped the early work of many of the most important painters of the modern age. Van Gogh's work was transformed when he came to Paris and saw their paintings. They gave him the inspiration to use bold, unmixed new colours with glaring brilliance, such as those in *The Night Café* (1888) (Figure 5).

Impressionism and Fauvism made colour a central constructive component of modern art. Georges Seurat depended on bright, bold primary colours to develop his influential "pointillist" style. Paul Gauguin began his career under the wing of Pissarro. Wassily Kandinsky initially painted in the Fauve style, and went on to try to develop a kind of universal language of colour. Georges Braque too passed through a Fauvist period before developing Cubism with Picasso. How much of this would have been possible without the development of the vibrant new pigments in the nineteenth century?

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Figures

Figure 1 Turner, *Ulysses Deriding Polyphemus* (1829). [Tate Gallery, London, I believe.]

Figure 2 Matisse, *Portrait with a Green Stripe* (1905). [Statens Museum for Art, Rump Collection, Copenhagen.]

Figure 3 Renoir, *Boating on the Seine* (1879-80). [National Gallery, London.]

Figure 4 Monet, *Lavacourt under Snow* (c. 1879). [National Gallery, London.]

Figure 5 van Gogh, *The Night Café* (1888). [Yale University Art Gallery.]