

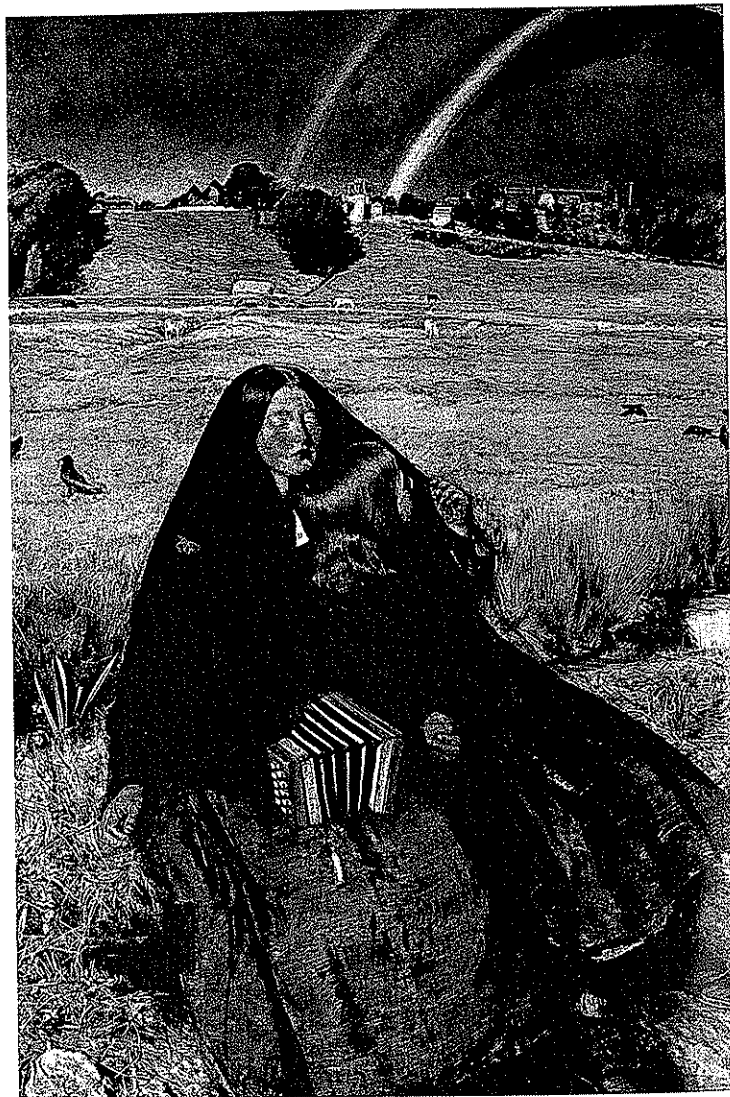


J O H N G A G E

# Color and Meaning

Art, Science, and  
Symbolism

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In his poignant study of visual deprivation, *The Blind Girl* of 1856, Millais's exact rendering of the landscape-setting did not extend to the secondary rainbow, where he failed to notice the reversal of the spectral colours until the mistake was pointed out to him by a friend. Imperceptible transitions of hue make the bow a particularly subjective scale of colour. (49)

## 8 · The Fool's Paradise

...that Triangular Glass call'd the fool's Paradise, though fit for the wits of wiser men, which representeth so lively Red, Blew and Green, that no colours can compare with them...

(Christopher Merrett, 1662<sup>1</sup>)

IN AN ESSAY OF 1983 THE DOYEN of modern students of medieval and Renaissance optics, David Lindberg, argued that 'there was much in sixteenth-century optics that was new, but nothing that was revolutionary'.<sup>2</sup> This was not a surprising conclusion given that Lindberg dealt with only two sixteenth-century writers, Francesco Maurolico and Giovanni Battista della Porta, and that his understanding of the history of optics was essentially confined to its geometrical branch, which traces a line from Euclid, through Robert Grosseteste and Theodoric of Freiberg to Descartes and Newton in the seventeenth century. But there are of course several histories of optics: one of them involves the medieval and Renaissance metaphysics of light,<sup>3</sup> and another, which I shall call 'perceptualist', runs from Aristotle through Alhazen and Witelo to Leonardo da Vinci and on to Chevreul in the nineteenth century (Chapter 15) and takes in Newton on the way. It is this 'perceptualist' history which is the subject of the present chapter.

These histories are not, of course, mutually exclusive; it is rather a question of emphasis; but I think it has been generally understood that the geometrical optics of the seventeenth century presented a quite new evaluation of the relationship of light to colour: where for Aristotle light was the activator of colour, and where for most medieval thinkers it was the vehicle of colour, for many scholars in the seventeenth century, notably Descartes and Newton, it came to be identified with colour itself. Colour was inherent in light, and light was the efficient cause of colour in all its manifestations, for colour was the inevitable consequence of the variable refraction of light. And so, by and large, it has remained. The 'perceptualist' account, on the other hand, is concerned, not with the causes of colour, but with its effects, with the way in which a radiant stimulation of the human visual system becomes identified as colour at all. In this account, which developed essentially within a tradition of medical research, the experimentation of the sixteenth century had indeed a major role to play.

The history of the rainbow, characterized in the classic study by Carl Boyer as 'from myth to mathematics', shows how a phenomenon which was traditionally seen as an exemplar of the nature and meaning of colour, became from the seventeenth century a demonstration of the nature of light, to which the perceptual characteristics of colour were largely irrelevant.<sup>4</sup> Seeing the rainbow continued

less dense to a denser medium shortens the distance travelled, and thus compensates for its slower velocity in that denser medium).<sup>15</sup>

Given that Grosseteste had proposed that sight and colour offered a paradigm of the corporeal and incorporeal elements in the Holy Trinity, and that his follower Bacon had urged the important theological significance of numerology, and had indeed argued that the equilateral triangle gave insights into the nature of the Trinity itself,<sup>16</sup> we might well have expected that Witelo's emphasis on the three active faces of his crystal would have led, by the power of symbolizing as well as by the principle of simplicity, to the development of the modern triangular prism. Certainly, in the fourteenth century the notion of the three colours of the Trinity was articulated very forcefully in a popular French devotional poem, Guillaume de Digulleville's *Pilgrimage of the Soul* (c. 1355). But so far from appealing to the rainbow, with all its traditional connotations of the Covenant between God and man, the bridge between Heaven and Earth, Digulleville exemplified his triad of colours in the unity of a single phenomenon, colour-change: the unchanging gold of the Father, the scarlet (*vermeil*) blood of the Son and the comforting green of the Holy Spirit, in the colours of the peacock and the shot-silk cloth which was also commonly associated with the colours of the peacock's feathers.<sup>17</sup>

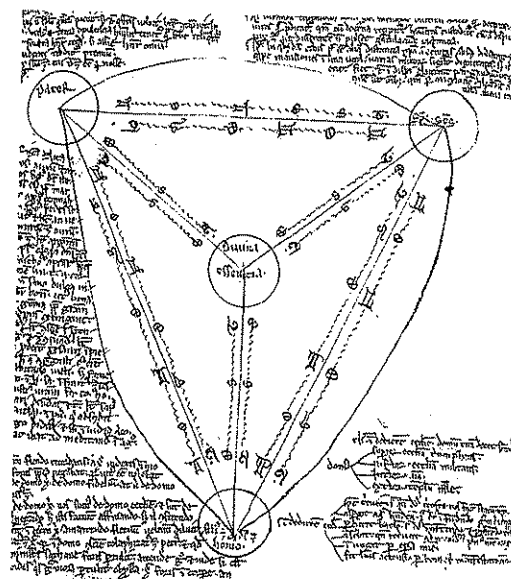
Bacon, in his lengthy discussion of the crucial usefulness of physics and mathematics in the *Opus Maius*, had adduced the equilateral triangle as a perfect image of the Trinity precisely because it was a figure which could be found nowhere else in nature. And of course, unlike the lense, whose early development was based on an analogy with the crystalline lense of the eye, the triangular prism is in no way a natural shape.<sup>18</sup> Perhaps in the thirteenth century the association of the Trinity with the triangle, a Manichean notion which had been roundly condemned by St Augustine, was still too theologically suspect; it only became less so in the early Renaissance, when the triangle appeared increasingly as the form of the halo of God. This suspicion was in spite of the growing popularity in the later Middle Ages of the triangular devotional image of the Trinity known as the *Scutum Fidei* (Shield of Faith), which seems to have been devised by Grosseteste himself.<sup>19</sup>

The triangular prism was thus an astonishing development: a purpose-built tool for which there were no precedents either in nature or in the Ancient world. The philosophical and theological contexts would have led us to expect its appearance no later than the fourteenth century, but there seems to be no evidence for it before the middle of the sixteenth.

### *The prism in the sixteenth century*

Albertus Magnus in his *Meteorology* (Iff, iv, 19) appears to have distinguished between the hexagonal rock-crystal called the *iris*, and a '*crystallo angulosa longa*' which had the same properties as the *iris*; but he gave no further details.<sup>20</sup> Witelo's *Optics* was well known in the early Renaissance – in Italy it was consulted by both Ghiberti and Leonardo da Vinci, who may have been introduced to it by the mathematician Luca Pacioli.<sup>21</sup> Ockham's logic of economy was also particularly

Robert Grosseteste's triangular diagram of the Trinity, the *Scutum Fidei* (before 1231), with Father, Son and Holy Ghost united in God at the centre. (51)



cultivated in Renaissance Italy, where his works were studied and published at Bologna in the 1490s.<sup>22</sup> Theodoric of Freiberg's work was less known, although it was summarized by Jodocus Truttfetter in his *Philosophie Naturalis Summa*, printed at Erfurt in 1517. Truttfetter's version is especially interesting, not least because it gives some precocious attention to the shifting Latin vocabulary of the rainbow-colours; and it also offers perhaps the earliest published analysis of the use of tonal contrast by painters in order to create the effect of space.<sup>23</sup> But in the present context what is most striking is Truttfetter's description of the optical experiments he conducted, using a darkened room with a single hole in the shutter to allow the sun's rays (*radii solares*) to enter and create colours by the interposition of various optical devices. Truttfetter mentions a mirror, a *cristallo longa ac angulosa*, and also the glass rod cited by Seneca in the first century AD (*Natural Questions*, I, vi, 7). He also lists the hexagonal stone called *iris*.<sup>24</sup> But he does not refer to the triangular prism; nor is it mentioned in the very popular sixteenth-century encyclopaedia, the *Margarita Philosophica* of the German Carthusian monk Gregor Reisch, which was published in a dozen editions, including Italian translations, between 1503 and 1600, although Reisch, too, mentions the hexagonal stone.<sup>25</sup>

It does not seem to be before the middle of the sixteenth century, and in Italy, that triangular prisms came to be part of the equipment of optical experiment. The Milanese physician and philosopher Gerolamo Cardano seems to be the first to mention the 'triangular crystal, or prism' in his scientific encyclopaedia *De*

sixteenth-century thought, particularly, through its variant the four humours, in the theoretical medicine of which Scarmiglioni was a professor.<sup>31</sup> All his major modern sources engaged with this question, although several of them were concerned about a conflict between the theory and their own experience. How, for example, asked Filippo Mocenigo, could fire, which was light and thus close to white, be embodied in coal, which was black? And how, asked the physician Girolamo Capodivacca, could cold snow be white? The Neapolitan polymath della

52 Porta, who also wrote on botany, used many examples from plant-life, including one called the *chameleon* by the Greeks, to argue that colour and substance were only tenuously related.<sup>34</sup> The visual characteristics of the four elements were indeed much in evidence in Scarmiglioni's Prague, where the Milanese painter Giuseppe

45 Arcimboldo had made a speciality of fantastic agglomerations of their respective attributes.<sup>35</sup>

In *De Coloribus*, Scarmiglioni, who had also lectured specifically on the temperaments,<sup>36</sup> reviewed the ancient and modern doctrines of the colours of the elements and could find little agreement among them. He claimed that the four temperaments cannot produce colours, since they are not themselves visible qualities; conversely, the essential causes of colours, opacity and transparency, are not among the traditional qualities attributed to the elements.<sup>37</sup> Scarmiglioni also argued that light, for example, may manifest itself in many colours: the sun may be yellow or red, the moon silver or blood-red, a flame blue (*coerulea*) or white.<sup>38</sup> Yet, unlike his contemporaries, he was not content to let matters rest there; he boldly advanced a theory that 'real' and 'apparent' colours were, in vision, essentially the same:

Apparent colour does not differ in respect of representation from real colour, for green is equally seen in the emerald and in the neck of a dove, blue in the sky... and in the peacock, in the triangular crystal and in the painted rainbow. They are called apparent colours because they only appear from one angle [*situ*] so that if the sun paints a rainbow in any falling drop of water, or thread of a spider's web seen from such an angle, it will be looked at from another [angle] in vain.<sup>39</sup>

And he explained that they are alike since they are all nothing but visible *species*, those emanations from objects which entered the eye, and whose propagation and characteristics had been the subject of much discussion in the Middle Ages.<sup>40</sup> Scarmiglioni adopted the traditional Aristotelian position that *species* rise from 'light and shadow',<sup>41</sup> but his subjective view that they were the cause of *all* colours seems to be original, and came to be reinforced by Descartes and Newton in the seventeenth century.

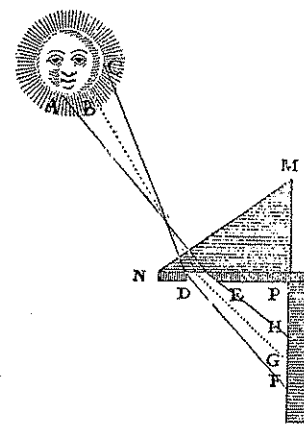
Scarmiglioni also argued that the Aristotelian notion of colour as activated by light on the surfaces of bodies was manifestly untrue, since gold, for example, looked yellow by moonlight but silver in the sun; thus the colour must be in the light, not in the surfaces.<sup>42</sup> Similarly he came to the unusual conclusion that, since colours are simply visible *species*, all colours must have equal validity. Instead of adopting the then-traditional division of colours into 'simple' and 'mixed', he said that 'all colours are equally simple'.<sup>43</sup> The important distinctions

were between the 'light' (*lucidi*) colours, as in the spectrum, and the 'obscure', as in matter.<sup>44</sup> All this looks remarkably familiar from a seventeenth-century point of view, but Scarmiglioni had reached his conclusions, not by the mechanical interpretation of refraction, but largely, as he said, through *quotidiana experientia*, everyday experience.<sup>45</sup>

Scarmiglioni was, nevertheless, far from indifferent to the problems of colour and refraction. We saw his reference to the 'triangular crystal' in the passage on apparent colours quoted above, and there are other chapters in his book where he dealt with the creation of spectral colours, for example the weak spectrum cast by the edge of the window-pane, and that produced by the triangular prism itself. Like so many of his contemporaries, Scarmiglioni seems to have used the prism as a lense to examine the prismatic fringes between the light and dark areas of surfaces. He was clearly impressed by the bright cyan blue at the junction of light and dark, which he called *hyacinthinus*, and by the appearance of red next to the dark, as light was replaced by dark, so that, like his immediate source, Filippo Mocenigo, who was also an experimenter with the triangular prism, he took the unconventional view that, in a tonal scale of hues, red is closer to black than is blue.<sup>46</sup>

Like Mocenigo too, Scarmiglioni thought that the appearance of colours depended on the thickness of the prism; and Mocenigo speaks of reversing the instrument, so that the red and the blue change places, while green remains constant between them.<sup>47</sup> This was an interpretation close to that of Albertus Magnus, and depended on the still very active notion that colours were the product of obscuring or modifying light, in this case, by the glass of the prism. The manipulation of the triangular instrument became a key procedure in seventeenth-century optics, notably in Descartes, Boyle and Newton, whose observations, of course,

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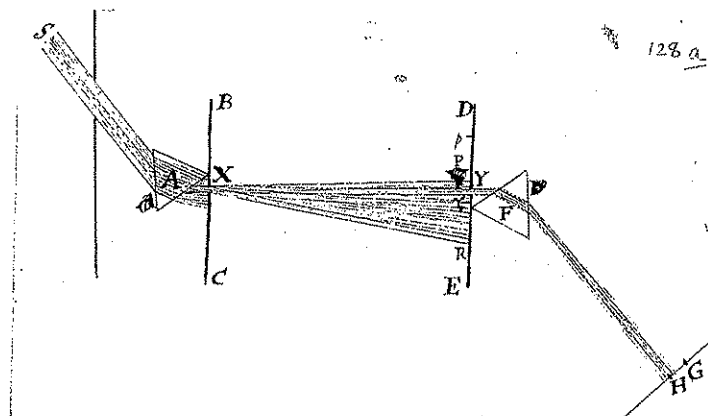
The philosopher René Descartes' prism-diagram of 1637. He shows a right-angled prism instead of the more usual equilateral form – whether of crystal or glass is not known. (53)

of this sort are those made and publicized by Goethe about 1790, observations which led him to refute Newton's theory that colours are a function of the variable refrangibility of rays of light.<sup>55</sup> But just as these indoor experiments prevailed, in Goethe's case, over his observation of the rainbow outdoors, so experiments with the prism before Newton brought little clarity to the question of the number and nature of the spectral colours.

The thirteenth-century German encyclopaedist Arnoldus Saxo identified four colours, *nubes, flavo, viridi ac citrino*, in the spectrum projected by the *iris*;<sup>56</sup> Albertus Magnus, although he was familiar with Arnoldus's work, opted for the Aristotelian triad of red, green, and that confusing colour *caeruleus*, which sometimes meant blue and sometimes yellow, although here it clearly means the latter.<sup>57</sup> Theodoric argued for four colours in the rainbow and the hexagonal prism, specifically including the yellow which Aristotle had regarded as a mixture of red and green, but which Theodoric and della Porta after him insisted was a principal colour. Yet in his prismatic experiments he mentions only red and blue.<sup>58</sup> Cardano in the sixteenth century saw four or five colours; Mocenigo identified three, although he also admitted that there might be others in between; and Scarmiglioni himself also seems to have been reluctant to identify the precise character and number of the colours, although he claimed that they were plain enough to see.<sup>59</sup> Harriot calculated the angles of refraction of five colours,<sup>60</sup> but della Porta's prismatic experiments revealed only three colours to him: red, yellow and blue (*rubens, flavus, caeruleus/lalurgus*).<sup>61</sup> Even Newton was to divide his visible spectrum into as many as eleven colours and as few as five, before finally settling on the seven, which, as we shall see in the next chapter, he was to adopt for the largely metaphorical reason that he was pursuing the analogy with the notes of the diatonic scale.<sup>62</sup> It is difficult to resist the conclusion that, as in the case of the rainbow at large, the perception of the prismatic spectrum was very much in the shadow of preconceptions.

Whatever the perceptual difficulties in identifying the colours in a prismatic spectrum, the origins of the triangular prism would still be of compelling interest even if it had been no more than the toy (the popular creator of the multicoloured 'fool's Paradise') which provided Descartes and Newton with their proofs of the quantitative nature of colour. The elegant simplicity of their arguments was made possible partly by the elegance of this simplest of tools. At some time during the two centuries between Theodoric of Freiberg and Gerolamo Cardano, some perspectivist must have decided to reduce the hexagon of the quartz crystal to a triangular form. It may well have been that a large hexagonal crystal was first sawn in half and polished; but this would still leave a good way to go before the adoption of the equilateral triangle which we see in the sixteenth- and early seventeenth-century illustrations.<sup>63</sup>

The balance of evidence suggests that this reduction took place during the early sixteenth century; but it is unlikely to have been achieved by Cardano himself, since, although he was proud of a number of his efforts to provide simpler explanations of the structures of nature, he included no allusions to optics in his autobiography, *De Vita Propria Liber*, where he listed his various and notable achievements.<sup>64</sup>



The diagram of Sir Isaac Newton's crucial experiment, 1666-72. A ray of light is divided into its constituent colours by the first prism, and the resulting bundle of coloured rays is reconstituted into white light by a second. (55)

Newton's *experimentum crucis*, developed between 1666 and 1672, in which two prisms were arranged so that the colours of the spectrum formed by the first were shown to be unmodified by the second, and were thus each the product of a single refraction,<sup>65</sup> depended upon the complete symmetry and reversibility of the triangular prism, noticed but not interpreted by Mocenigo about 1580. Seldom can so simple a device have been so freighted with important consequences, but seldom, too, can it have developed so slowly as did the prism, from its theoretical grounding in the thirteenth century to its practical realization in the fifteenth and sixteenth centuries, and its effective use in the seventeenth.

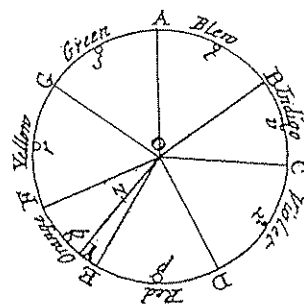


had been clarified over the previous half-century or so through the experience of mixing paints. Robert Boyle, in a treatise of 1664 which stimulated Newton to make some of his earliest colour-experiments, claimed that

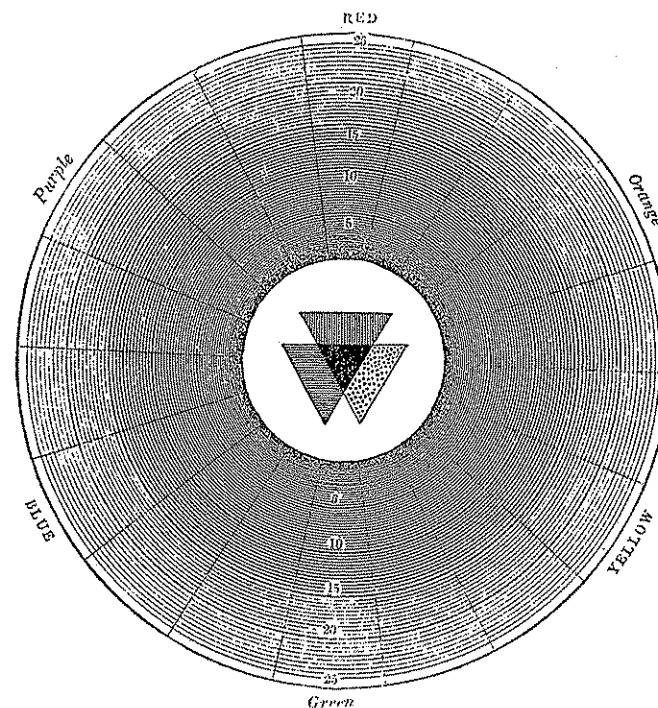
much of the Mechanical use of Colours among Painters and Dyers, doth depend upon the Knowledge of what Colours may be produc'd by the Mixtures of Pigments so and so Colour'd. And... 'tis of advantage to the contemplative Naturalist, to know how many and which Colours are Primitive... and Simple, because it both eases his labour by confining his most solicitous Enquiry to a small Number of Colours upon which the rest depend, and assists him to judge of the nature of particular compounded Colours, by showing him from the Mixture what more Simple ones, and of what Proportions of them to one another, the particular Colour to be consider'd does result.<sup>8</sup>

Boyle had already stated that these few 'primitive' or 'simple' colours of the painter were black, white, red, yellow and blue.

But Newton had thrown this neat symmetrical scheme of simple colours into confusion in his first paper of 1672 by showing that there were as many 'simple' (or 'primary', 'primitive', 'uncompounded', 'original', or 'homogeneous') colours as there were refrangible rays of light,<sup>9</sup> and that these same colours (for example green, and even yellow) might occur in both a simple and a compounded form. Newton's leading opponent on this occasion, Robert Hooke, who had himself developed a radically reductive theory of only two primary colours, understandably sought to apply Ockham's Razor;<sup>10</sup> and during the eighteenth century Newton's number of primaries (which was generally and erroneously thought to be seven) continued to present something of an obstacle to students with painterly connections. And yet the circular diagram of colour-mixtures which Newton introduced in the *Opticks* of 1704 gave promise that a white might indeed be compounded from two or three of the colours lying opposite each other, which could thus be regarded as primary by themselves.<sup>11</sup> Newton claimed in the text to this figure that he was never able to mix more than a 'faint anonymous Colour' by means of the proportions indicated; but in his experiments with the mixture of coloured powders (I, ii, prop. v, theor. iv, exper. 15), he had succeeded in making a 'mouse-colour' (his surrogate for white in



Sir Isaac Newton's colour-circle, from the *Opticks* of 1704. It was devised for mathematical calculation of the constituents of mixtures, and its asymmetry reflected the proportions which Newton ascribed to the spectral colours. (58)

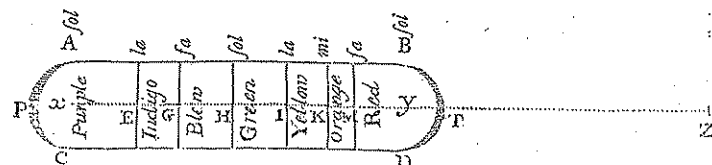


Colour-circle from Moses Harris, *The Natural System of Colours*, c. 1776. Harris's is probably the first completely symmetrical circle of primary and secondary colours, and it also suggests the progressive darkening of each hue to black at the centre. (59)

pigment-mixtures) with only two: one part red lead and five parts copper-green, which he concluded, to save his theory, must themselves be compounds of other colours.

This circular diagram became the model for many colour-systems in the eighteenth and nineteenth century, from the supplement to the *Traité de la Peinture en Mignature*, attributed to Claude Boutet, in The Hague edition of 1708, where the seven-colour division (with two reds) seems clearly to reflect the Newtonian arrangement of four years earlier, to the first completely symmetrical and complementary colour-system of Moses Harris, *The Natural System of Colours*, published about 1776. Newton's scheme provided, too, the starting-point for the first attempt to apply the Newtonian system to the practical problems of colour-mixture, published by the Cambridge mathematician Brook Taylor in the second edition of

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 Y the centres of those semicircles, X Z the length of a musical string double to



X Y, and divided between X and Y, so as to sound the tones expressed at the side (that is X H the half, X G and G I the third part, Y K the fifth part, Y M the eighth part, and G E the ninth part of X Y) and the intervals between these divisions express the spaces which the colours written there took up, every colour being most briskly specific in the middle of those spaces.

Sir Isaac Newton's correlation of the intervals of the spectrum with the musical scale, first devised in the 1670s though not published until the following century. (60)

... as the harmony and discord of sounds proceeded from the proportions of the aerial vibrations, so may the harmony of some colours, as of golden and blue, and the discord of others, as of red and blue, proceed from the proportions of the aethereal. And possibly colour may be distinguished into its principal degrees, red, orange, yellow, green, blue, indigo and deep violet, on the same ground that sound within an eighth is graduated into tones.

For, some years past, the prismatic colours being in a well darkened room cast perpendicularly upon a paper two and twenty foot distant from the prism, I desired a friend to draw with a pencil lines across the image, or pillar of colours, where every one of the seven aforementioned colours was most full and brisk, and also where he judged the truest confines of them to be, whilst I held the paper so, that the said image might fall within a certain compass marked on it. And this I did, partly because my own eyes are not very critical in distinguishing colours, partly because another, to whom I had not communicated my thoughts about this matter, could have nothing but his eyes to determine his fancy in making those marks. This observation we repeated divers times, both in the same and divers ways, to see how the marks on several papers would agree; and comparing the observations, though the just confines of the colours are hard to be assigned, because they pass into one another by insensible gradation; yet the differences of the observations were but little, especially towards the red end...<sup>21</sup>

It seems clear that, in spite of Newton's efforts to make the experiment 'objective', the isolation of seven prismatic colours was itself the result of the musical analogy, in which he had been interested for some years.<sup>22</sup> The conception of the especially harmonious character of a combination of gold and blue which (shifted to indigo in the *Opticks*, as purple was renamed violet), and the discord of red and blue, have no justification other than their relative places in Newton's scale.

The general conception of numerical harmonies in colours had an Aristotelian origin, but Aristotle (*De Sensu*, 439b) had confined it to the light and dark components of single hues rather than an assortment of hues; and the closest precedent for Newton's view is in a remarkable study of the rainbow published by Marin Cureau de la Chambre in 1650. Cureau de la Chambre, however, did not use a prismatic spectrum, but an Aristotelian scale between black and white, yet he agreed with Newton that blue was dissonant with red and consonant with yellow.<sup>23</sup>

It was Newton's suggestion in Query 14 of the *Opticks*, however tentatively expressed, which provided the chief stimulus to the study of colour in the first half of the eighteenth century, both for Le Blon and for another unsuccessful projector who sought to materialize the theory of correspondences, the French Jesuit Louis Bertrand Castel, the inventor of the ocular harpsichord, which became a *cause célèbre* throughout Europe in the latter part of the century.

In the first brief outline of his idea in 1725, Castel traced its inception to some hints by the mid-seventeenth-century polymath Athanasius Kircher, but more immediately to Newton's *Opticks*, 'that excellent book', which had 'verified' the link between sound and light. He secured professional help to design an instrument embodying the analogy by means of a keyboard controlling coloured-glass filters and mirrors; but the prototype, which was ready by 1730, appears to have been rather simpler. Castel began the building of a full-scale version in 1734, but the account which he published the following year shows that he had by now moved away from any Newtonian scheme. He had come under the influence of the composer and theorist of harmony, Jean-Philippe Rameau, who had encouraged his project from the first, and he had adopted a scale based on the three primary colours, red, yellow and blue, of which blue was analogous to a musical ground-bass (*basse fondamentale*). Castel thought blue to be equally close to white and black, the traditional origins of all colours, and it is indeed a colour which retains its true identity over a remarkable range of tonal values. Blue he gave the note-value of C, yellow of E, and red, 'the dominant colour of nature', of G.

Rameau had published his first treatise on harmony in 1722, and also regarded the base as fundamental; he, too, had developed a triadic theory of harmony in which the consonances of the fifth and the two thirds were primary, and gave rise to the three secondary consonances, the fourth and the two sixths.<sup>24</sup>

It may well be that Castel adopted his scale of three colours from Le Blon, whose printing-process he had witnessed in 1732, for, as he noted in a review of *Coloritto* a few years later, that process also treated blue as the fundamental colour, with which the sequence of impressions began.<sup>25</sup> But notwithstanding Le Blon's Newtonian pretensions, by the time of his most important publication, *L'Optique des Couleurs* of 1740, Castel had become the most extravagant of anti-Newtonians, and had rejected all prismatic studies in favour of the exclusive investigation of colouring-materials. The ocular harpsichord, which was now based on a twelve-colour circle and a chromatic scale of twelve notes over twelve octaves, was apparently completed in the 1750s, and may have been demonstrated in London and Paris.<sup>26</sup> In any case it was the ancestor of the many instruments which have sought to present colour in motion, with or without a musical analogy, until our own times.<sup>27</sup>