CHAPTER 12

Refining the colour circle

Introductory

At my painting school, I give talks on colour-mixing. This chapter and the next three chapters are based on these. Between them they flesh out some of the claims made in the previous chapter and provide a sound and practical approach to colour-mixing. My aim is to help people with:

- *Finding a maximum of colours in any part of the colour sphere, as described in the last chapter.*
- *Creating a sense of light and space in paintings.*

The first of my talks (the subject of this chapter) concerns colour-mixing by stirring. Experience has shown that for many people coming to my Painting School for the first time, it is necessary to start my explanations at the most basic levels. Accordingly, I introduce my talk by apologising in advance for going over ground that may already be familiar to some, but suggest that it is better to be absolutely sure of building on common and solid foundations.

TESTING EXISTING KNOWLEDGE

The first step is to find out what my students already know, which I do via a series of questions, starting with ones concerning the "*colour-circle*". As this is featured in just about every book and article, I am often surprised to find how vague people can be about it, even if they have been actively painting for many years. Nevertheless, it is usually possible to elicit the following information. Thus, I am told:

- That the colour-circle is divided into six segments, representing three primary and three secondary colours.

- That the three primaries are red, blue and yellow.
- That the three secondaries are mixtures between remaining two primary pairs, that is to say: for red, (*yellow + blue)*(b), for blue, (yellow & red), and for yellow, (blue & red).
- On the basis of this information, I make a rough drawing of the colour-circle along the lines of the one illustrated in *Figure 1*. In this each of the six segments is labelled with the first letter of the appropriate colour.

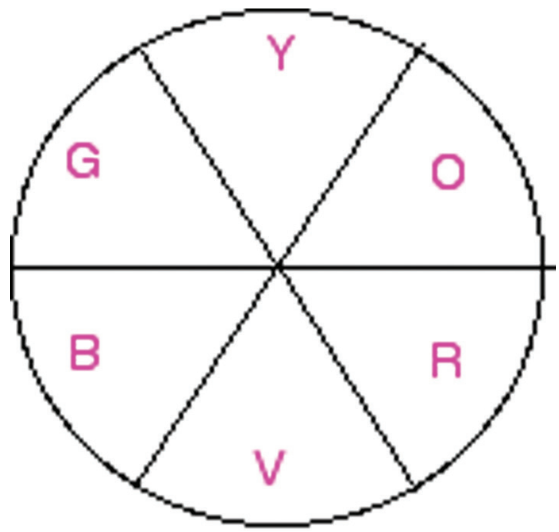

Figure 1 : A six segment colour-circle

The next question concerns the definition of a "*primary*". When asked, the students usually come up with the standard answer to be found in most books. It consists of two statements. These are that:

- The primaries are the only colours that cannot be mixed from combinations of other colours.
- All other colours can be made from mixtures of them.

CHECKING OUT THE DEFINITIONS

Having established definitions, I check them out by turning to particular colours, starting with greens. For example, I might choose, an *oxide of chromium green* or a *viridian*. According to the definitions just enunciated, green is a *sec-*

ondary colour and should be able to be created out of a mixture of primaries.

The question arises as to whether this is true. Is it actually possible to mix the green in question using a combination of one yellow pigment-colour, one blue pigment-colour and, if necessary, one red pigment-colour? Most of my students are disconcerted when I assert that it is not.

The same line of questioning can be taken further. The most widely used blues are *Cobalt, French Ultramarine, Cerulean, Prussian*, and, the latter's modern substitute, *Pthalocyanine* blue.[1] The theory states that there is *only one primary blue*. So, which of these is it? The students very often have views on this subject and plump for one or other of the blues listed (though by no means consistently the same one). If their choice were to be good and the theory of the three primaries were to be true, then it should be possible to match the remaining blues by combining the chosen blue with an appropriate combination of the other two primaries.

Accordingly, I ask my students whether they would like to do the appropriate colour-mixing experiment. By this time, the penny is beginning to drop and one of them will venture something along the lines of, "*I suppose you are going to tell us we won't be able to*", which, indeed, is exactly what the experiment will prove to them, no matter which target colour they have chosen. And so the story goes on, for irrespective of what tube colour I choose, the answer will always be the same: it will never be possible to match it with a mixture of other colours.[2]

To hammer the point home, I produce an anecdote, followed by a scientific explanation. The anecdote concerns a student who was trying to decide whether to afford a tube of *oxide of chromium green* (one of the more expensive colours). He explained to me that he had decided to purchase it only if he failed to mix an identical colour from the impressive range of pigment-colours already in his box. So he set to work. At the end of a morning of activity he had covered a large sheet of canvas board with a plethora of trial colours. However, despite his efforts, he was forced to admit defeat and, consequently, bought the tube of paint.

Spectroscopy

The scientific explanation requires an understanding of the nature of *spectroscopy*. This is one of the major tools of modern science. It enables scientists

1 Often known by trade names such as "*Monastial Blue*" or "*Winsor Blue*".

2 Although it is sometimes possible to get very close indeed, particularly with already highly desaturated colours such as browns, ochres and earth reds.

to analyse substances and classify them with an extraordinarily high level of certainty, even when they are as far away as the planets and the stars. To explain how it works, it is necessary to understand that light that strikes and enters into a surface is either completely or partially absorbed by the pigment it encounters. The degree of absorption determines the amount of light that will be scattered-back out from the surface. The spectrometer, the measuring tool of spectroscopy, makes a record of these absorption and reflection characteristics.

The principle upon which the spectrometer works is easy to explain by reference to *Figure 2*, which illustrates the components of a beam of white light being separated out by a prism. Imagine that the emerging spectrum of colours is directed towards a thin sheet of opaque material (the black line) containing five horizontal slits each allowing only a very narrow band of wave-lengths to pass through it. If we looked through this grid of slits from the opposite side to the prisms (the bottom half of *Figure 2*) the lowest slit, which is in the right position for viewing the shortest wave-length end of the spectrum, would be perceived as indigo. If we looked at the highest slit, which is in the right position for viewing the longest wave-length end of the spectrum, it would be perceived as red. The intermediate slits would appear as the intermediate colours as illustrated.

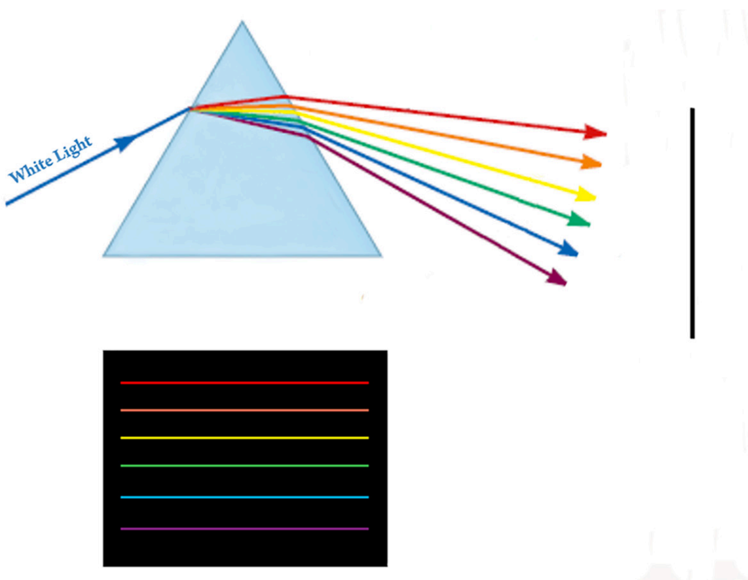

Figure 2 : The prism separates out the white light into the "prismatic colours".

It is not difficult to imagine that it would be possible to refine this simple idea so as to produce a machine capable of emitting a gamut of different wave-lengths of light such that each could be shone separately onto a target substance with a view to discovering whether it is absorbed or reflected. The two main refinements required to produce such a machine were sufficiently powerful beams of light and easily readable outputs or "*spectrograms*" as illustrated in *Figure 3*.

Figure 3 : Some spectrograms and a bar code

At the top of the *Figure 3* is a bar-code typical of the kind found on products sold in shops. Its purpose here is to provide a familiar analogy of the formidable classifying power of the spectrogram. We all know that bar-codes can distinguish between all the products sold in a huge supermarket and many more. The classifying power of the spectrogram is limited only by design. In theory it could be *infinite*. Even a machine using 20 wavelengths and 20 brightness steps would be sensitive to an astronomic number of different combinations.

Scientists have discovered an enormous amount from spectrograms. In the present context, The most important one of these is the simple fact that *no two substances have the same absorption/reflection characteristics*. As well as being remarkable in itself, this conclusion is something artists should ponder upon. It is that every one of the different pigment-colours used by artists must be unique.

The lesson is clear: Any attempt to reproduce no-matter-what particular tube-colour by making a mixtures of no matter what other tube-colours is doomed.[3]

Parent colours

If it is true that no tube colour can be mixed from combinations of other colours and if we accept the definition of a "*primary*" is that it cannot be made from mixtures of other colours, it follows that according to this definition:

- *All tube colours can be defined as primaries.*

But that is not all. Since the second part of the definition of a primary states that all other colours can be made from mixtures between it and combinations of the other primaries, it also follows that:

- *The larger the number of primaries used as parent colours, the greater the number of different colours can be created.*

It hardly needs pointing out that the above conclusions challenge a great deal of received wisdom. This being the case, artists engaged in paint mixing should drop the term "*primary*". My suggestion is that they use the phrase "*parent colour*".

Matching colours in nature

A parallel argument can be applied to the problem of matching natural-world colours, including any of:

- The multitude of greens of leaves.
- The different yellows, oranges, reds, violets, blues and whites of flowers.
- The numerous earth colours.
- The wide range of flesh colours.

Or, indeed, the colour characteristics of absolutely any surface. Since all have unique absorption/reflection characteristics, it follows that it must be impossible to reproduce them (even if, in some cases, the matches can be extremely close.).

In short, the claim that colours in nature can be exactly reproduced is a myth. This explains why, though many have tried their best, *there is not a single example of an artist in history that has ever succeeded in producing genuinely natural colours.*

This point is important and gives extra force to the assertion of Cézanne that

3 Unless the colour concerned is already a mixture of tube-colours made up by the manufacturer.

the objective of painting from observation is not to imitate natural appearances but "t*o create a harmony that runs parallel to nature*". Artists who seek to achieve any more than this will be battering their heads against the proverbial brick wall.

Where does this leave the colour circle and the colour sphere?

At this point readers might well be beginning to wonder whether I am working towards suggesting that the "*colour-circle*" and the "*colour sphere*" should be consigned to the dustbin of history. Not at all. Both, when properly presented, are fundamental to the proper understanding of colour-mixing. The sole reason for debunking the mischievous and commonly held misconceptions discussed above is to clear the way for a different approach to the colour-mixing in which the ***colour-circle*** and the ***colour sphere*** are treated as ***conceptual tools***. Once this has been done, they become not merely good ways of thinking about colour-mixing but by far the best of them.

FURTHER REFINEMENTS

Before explaining how to maximise this potential, experience with students shows that they are in need of three further clarifications. This is be many of them are extremely vague as to what is meant by the "*best three primaries*" and the concepts of "*additive*" and "*subtractive*" colours.

The best three primaries

It should be emphasised that none of the above is meant to suggest that there are not three pigments (a red, a blue and a yellow) which will produce a larger or, according to requirements, a more desirable range of colours than any other combination of three. Indeed, an enormous amount of research done on the behalf of the printing trade has gone into discovering the best three primaries for the purposes of producing the most faithful prints of photographs and artworks using the smallest number of pigments. However, the existence of books and journal articles which discuss the merits of alternative "*best three primaries*" provide strong support for my point. The use of the word "*best*" makes it clear that they do not aspire to provide any such thing as actual primaries but merely a "*best compromise*". Nor do their efforts change the fact that even in the printing trade, the experts assert that best results always involves many more than three.[4] For

4 One of my students who is in that trade said that the general view is that eight primaries are

the painter, the search for the best three primaries has very little to recommend it since, no matter what the conclusion, restricting one's palette to three colours can only hinder explorations within colour-space. Of particular significance is the fact that it makes it a great deal more difficult to avoid repeating colours.

Additive and subtractive primaries are not the same

The theory of the three primaries is based on the research which shows that all colours are mediated by three different cone receptor types in the retina of the eye, each of which is maximally sensitive to different band of wavelengths of light. Experience with students shows that it is prudent to say something about these. The cone receptor which responds most strongly to the shortest wavelengths is usually referred to as the "*blue*" receptor. The one that responds most strongly to the longest wavelengths is usually referred to as the "*red*" receptor. And, the one that responds most strongly to the intermediate wavelengths is usually referred to as the "*green*" receptor. It is the name given to this third one that puzzles many people. They say, "*Surely, the third primary should be yellow*"?

To overcome this conceptual block it is often necessary to point out that the set of primaries used for mixing with coloured light are not the same as those used for mixing with paint. The two different sets are generally distinguished by calling the primaries made by mixing different wavelength combinations of light as "*additive*" and the ones made by mixing different paint colours, as "*subtractive*".

As the subject of the difference between additive and subtractive colours has been dealt with elsewhere, in *Chapter 10* and in many other books, there is no need now to do more than review a few key ideas. Thus, a basic fact of ***additive*** colour-mixing is that when any two light sources are combined into one beam, the result is an *accumulation* of light energy. This means that the colour produced is *more intense* and, consequently, *lighter* than either of the parent colours. Taking the idea a bit further, it follows that:

- Each of the three secondary light-colours (and indeed all other colours made by mixing beams of light), is *more intense* and *lighter* than the colours from which they are created.[5]

needed to get the best results.

5 Thus, for light mixtures:

- Violet is brighter than either the blue or the red which have combined to make them,
- Blue-green is brighter than either the blue or the green which have combined to make them and,

- The white light produced by all three beams is the *most intense* and *the lightest*.

Logically, this means that the *lightest* and *most intense* light-created colour, which we all experience as "*yellow*", cannot be a primary. In fact it is a mixture of "*red light*" and "*green light"*. As we shall see in *Chapter 16*, this counter-intuitive state of affairs turns out to be very important when it comes to understanding the fundamental difference between mixtures of opaque pigment-colours and those of translucent ones.

THE COLOUR CIRCLE AS A CONCEPTUAL TOOL

The remainder of this chapter is concerned with describing a more elaborate version of the colour circle that I present to my students in the course of my colour-mixing talks. Although there is nothing very original in it, there are various points which experience shows need emphasising.

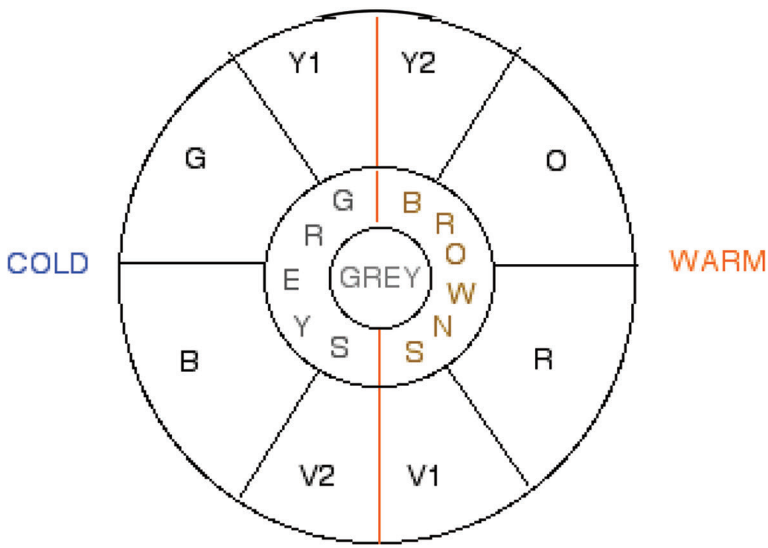

Figure 5 : A more elaborate version of the colour-circle

How many segments?

Evidently any two colours that are adjacent on the colour circle can be mixed

- Yellow is brighter than either the green or the red which have combined to make them.

to make an intermediate colour that would increase the number of segments in the colour circle. Nor is there any reason why this new colour should not be mixed with either or both of its neighbours to create the possibility of even more segments. Since this is the case, it follows that there is no reason why a colour-circle should not contain a very much larger range of hues than the six illustrated in *Figure 1*. For example, the *Munsell Book of Colours*,[6] the scientific reference for colour matching, has seventy-two pages, each representing the lightness and saturation ranges of one hue. The same range of colours can be displayed as a seventy-two part colour circle. Nor, as will be suggested below, is this the limit.

Although useful for the purposes of science and industry, the difficulty of keeping a lot of colours in mind renders a circle with too many segments unwieldy as a way of thinking about mixing paint colours. A much smaller number makes everything so much simpler. Six serves our present purpose admirably, although, as we shall see there are good reasons for adding more.

Elaborating a six segment colour-circle

My colour-mixing talk continues with suggestions for the series of modifications of *Figure 1* illustrated in *Figure 4*. Each is made for a reason and each needs some explanations. In providing these, my first concern is to explain how the boundaries between the segments are determined. For example, at what point on the colour circle does a yellow change into a green, a green into a blue, a blue into a violet, a violet into a red, a red into orange or an orange into a yellow?

Genetically determined divisions

With such boundary questions in mind, I add the vertical orange line to the original six segment colour circle, such that it runs down the middle of the yellow and the violet segments. This line, I explain, has great significance in that it is the only division in the colour-circle which has a *genetically determined* basis. Thus, if normally-sighted people[7] of any nationality or race are presented with a row of colours stretching from green to orange, each one of which is only just noticeably different (JND) from the next, are asked where the dividing line is between the last green-yellow and the first orange-yellow, everyone will choose the same place. Similarly, there is general agreement as to the division between blue-violets and red-violets.

6 Munsell Color, 1976, Macbeth Division of Kollmorgen Corporation, Baltimore.

7 That is to say trichromats.

Individually determined divisions

If the same question is asked concerning the division between any other colour circle neighbours, there will almost certainly be considerable disagreement. For example, it is *very unlikely* that there will be unanimity over the division between blues and greens or between reds and oranges. The reason is that, in the absence off a genetically-determined, psychophysical basis, colour attributions have had to be *learnt*. This means that, for each person, the relation between the name and the colour depends on what he or she has learnt from some influential person in his or her life, such as their Mother or their teacher. Since neither Mothers nor teachers can be relied upon to agree on colour naming, it follows that neither can their progeny. Most people must have witnessed (or participated in) disputes over colour naming and will know that they can be surprisingly acrimonious. All the disputants are equally sure that they are right, and in a very real sense, so they are. The problem is that each of them has learnt a different and incompatible "*right*".

Cold and warm colours

Much reference is made to "*cold*" and "*warm*" colours. *Figure 4* illustrates the notion that the colours on the red/orange side of the vertical dividing line (right) are defined as "*warm*" and those on the blue/green side of it (left), as "*cold*". Few will find difficulty in sensing a difference with respect to the "*warmth*" when comparing blues and greens with oranges and reds. Accordingly, it seems natural to describe the difference between adjacent yellows on the two sides of the genetically determined dividing line just mentioned in terms of *warm yellow* and *cold yellow* and, similarly, the adjacent violets as *warm violet* and *cold violet.*

However, this is not the end of the story for, although this division of the colour circle into a warm half and a cold half clearly has validity, the situation is complicated by the fact that some people talk about "*cold reds*" and "*warm blues*", both of which groups are clearly on the wrong side of the dividing line. One way of explaining how these can be fitted into the scheme of things is to do a thought-experiment in which colour temperature is related to a more normal use of the word "*temperature*", namely, when it is used as a measure of heat.

Imagine that there are three bowls of water. One is cold, one hot and the other half-way between the two. If we put our hand, first, into the cold water and then, immediately, into the medium temperature water, the latter will seem relatively warm. In contrast, if we had put our hand into the same medium temperature water immediately after it has been in the hot water, even though its measured temperature remains the same, it will now seem relatively cold. The reason is that in heat perception everything is relative.

This simple thought-experiment helps us with our understanding of colour perception because in that also (as indeed it is in all other modes of sensory perception) *everything is relative*. Accordingly, if we compare a blue that reflects to a significant degree in the red, longer wavelength part of the spectrum (for example, French Ultramarine) with a blue which reflects comparatively little in it (for example, Cobalt Blue) the former will be perceived as being warmer than the latter. Moreover the same sense of colour temperature difference can be achieved by mixing a small proportion of colour from the warm side of the colour-circle into any colour from the cold side. The colour that results will always be sensed as warmer than the parent colour. In the same way any blue,[8] or for that matter any green, cold-yellow or cold-violet can be made to feel relatively warmer by adding a touch of pigment from the warm side of the colour circle. Similarly reds, oranges, warm-yellows and warm-violets can made so that they are perceived as being relatively cold as compared with the parent colour.

In addition to using a sense of colour-temperature as a guide when painting from observation, it can be related to an aesthetic theory. Many teachers suggest that a good balance between warm and cold is necessary to achieve harmony within paintings.[9] My personal reaction to this claim is that, while it is easy to believe that such a balance may be a way of producing a certain kind of harmony, it is difficult to accept that it could be the only way of doing so.

Greys, browns and complementaries

When I ask students what is produced when red and green are mixed, the response is either "*grey*" or "*brown*". Actually both answers are right, but each reveals a different way of thinking about the question. Those who opt for "*grey*" may well have been influenced by what they have learnt concerning colour mixing theory.[10] In contrast, those who opt for *brown* are almost certain to be doing so on the basis of experience of making actual mixtures between actual pigment-colours.

8 Even one that has just been made to seem warmer in the above mentioned way

9 Johannes Itten, 1970, *The Elements of Color*, Van Nostrand Reinhold. New York.

10 They will almost certainly have seen a colour-circle with grey at the centre, as in Figure 4.

A fuller explanation for this divergence requires going back to basics and providing an explanation for the first answer in terms of the *theory of complementaries* (opposite colours on the colour circle), although, as we shall see in the next chapter, this oversimplifies matters, for there is another very different explanation. Thus, the opposites in the six segment colour-circle such as the one illustrated in *Figure 4* always consist of a *primary* and a *complementary* with the latter always being a *secondary colour* made out of a mixture of the other two primaries. Thus:

- Red is the primary and green the complementary, comprising a mixture of yellow and blue.
- Yellow is the primary and violet the complementary, comprising a mixture of red and blue.
- Blue is the primary and orange the complementary, comprising a mixture of yellow and red.

From this list, it will be seen that all the three mixtures between a primary and a secondary comprise the same three parent-colours (that is to say red, yellow and blue) and, accordingly, should be an identical neutral colour (that is to say grey). But in practice they never are.

The explanation for the mismatch between theory and practice is simple. The theory depends on there being pairs of actual pigment-colours that are indeed complementary, but the reality of the situation is that no such pairs exist. True, there are a few *near-complementary* pairs,[11] but none of these fit the definition of a true complementary as can be easily established by comparing any grey-seeming mixture made from any of them, with a grey made from a mixture of black and white. The two will never be exactly the same, which is another way of saying that they will never be truly neutral. Nor, in view of the earlier explanations of the absorption/reflection characteristics of pigment-colours, should we be surprised that this is the case. In view of the uniqueness of the spectrogram of every one of them, it would be a remarkable chance indeed had the forces of evolution provided us with any pair of artists pigments that fit the theoretical definition of true complementaries, particularly in view of the smallness of the number of artists' pigment-colours available.

Faced with the situation that we can never make a pure grey from mixtures

11 Two favourites are Alizarin Crimson and Pthalocyanine Green and French Ultramarine and Burnt Umber.

of what can only be near-complementary pairs of actual pigment-colours, we might wonder what colour such pairs might produce. As *Figure 4* indicates we can suspect that, if ever the mixture has a preponderance of a colour from the warm side of the colour circle, the answer will be some kind of brown. Here are two reasons why this might be the case with mixtures of red and green:

- It could be related to the naming the parent-colours. Thus, if, as is so often the case, the conception of a red that we learnt as a child is an orange/red and our idea of a green is a yellow/green, the result will have little in common with a theoretical complementary pair. Accordingly if either a yellow red or a yellow green (or both) are used in a supposed mixture of complementaries, there will be too much yellow in the mixture to create the necessary balance of the three primaries. The result will be a warm-orange-grey, which, as indicated *Figure 4,* is one way of characterising a brown.
- The red and or the green might be relatively opaque pigments. As I shall be explaining in *Chapter 16*, opaque and translucent colours mix according to significantly different principles. Accordingly, the issue of translucency versus opacity opens up a Pandora's box of problems for anyone who is intent on making sense of conventional colour-mixing rules.

All this is represented in *Figure 4* by the region labelled "*brown*" situated to the right of the small grey centre circle of the colour-circle. Its position indicates that a mixture between any complementary pair can produce a brown as long as there is a small preponderance of a colour on the warm side of the colour-circle. In this case, there is no need to be concerned with the concept of complementary pairs, since the rule will work just as well with near-complementaries and, indeed, not-so-near-complementaries just so long as they are found in the warm half of the colour circle. Thus, browns can be made by mixing any of the following combinations:

- Warm-yellow plus cold-violet.
- Orange plus blue.
- Red plus green.
- Warm-violet plus cold-yellow.

Figure 4 also illustrates the fact that, just as mixtures of complementary pairs in which there is a preponderance of the warm colour will make "*browns*". Similarly, mixtures of complementary pairs in which there is a preponderance of the cold colour will make colours that are normally described as "*grey*" whether tending to violet, blue, green or yellow. These additional greys are represented by the part of the diagram which is in mirror-symmetry with the browns region and situated just to the left of the theoretical neutral-grey centre of the circle. From this, it is easy to see that there are many more colours that are normally described as "*greys*" to be found on the cold side of the colour-circle than on its warm side. This will hardly come as a surprise to anyone.

Implications

In this chapter various qualifications to the conventional presentation of colour theory have been suggested. In particular:

- *The theory of three primaries has been questioned, not in its theoretical form, but as it relates to the actual pigment colours available to artists. It is argued that, since none of the tube colours used by artists can be mixed from other tube colours and since all artists colours have the capacity to extend colour-space beyond where it could reach without them, they can all be described as "primaries". However, in view of the confusion with existing misunderstandings, it would be better to describe them as "parent colours".*
- *A second suggestion is mooted as to why the degree of opacity or translucency of the pigment in paints effects the outcome of mixtures, most noticeably between pigment-colours on the opposite side of the colour circle. This will be elaborated upon and illustrated in the next chapter.*

As a result of these qualifications, it become clear that thinking of colour-mixing theory in terms of actual pigment-colours is almost certain to result in confusion.

In contrast, considering the colour-circle and the colour-sphere in purely conceptual terms leads to many extremely practical clarifications and simplifications. For this purpose the six segment colour circle and the simplified version of colour space shown in Figure 1 is ideal. It is to ways of making use of these that we turn in the next two chapters.