CHAPTER 26

Cast shadows as body colour

Introductory

The last chapter focused on further examples of ways in which the Mach Band phenomenon influences appearance in natural scenes and thereby causes artists problems with the control over whole-field relations in their paintings. In this chapter we consider the influence of simultaneous-lightness-contrast on cast shadows. Both phenomena are manifestations of Chevreul's rule that differences in lightness existing at the common border of adjacent regions of colour are exaggerated by the eye/brain. There is one big difference between Mach Bands and shadows. While each Mach band is flanked by a lighter colour on one side and a darker one on the other, a cast shadow is normally flanked on all sides by very much lighter colours.

As explained at the beginning of this Volume, in the 'Introduction to the Science', the eye/brain parcels out different visual tasks to different visual systems. Of particular interest when considering shadows are the ones which separate out reflected-light from body-colour.[1] *As a by-product of the way they achieve this little miracle, cast shadows are mistakenly classified as regions of body-colour. Accordingly, as far as the eye/brain is concerned the blacks and greys of shadows are just as much body-colour as reds, blues, greens, purples etc.*[2] *This is why shadows are being dealt with under the heading of "Painting with Colour".*

More precisely, when confronted by cast shadows, the eye/brain classifies them as low reflecting versions of the pigment colour they fall upon. The stronger the lightness contrast between the shadow and its context, the darker they appear to be. Also, the nearer they approach to being black, the more they dominate the underlying body-colour. Often it can be difficult to pick up any information at all

1 See, "*Second Introduction: The Science behind the Art*".

2 See Semir Zeki on colour-coded cells.

about the body colour of the surface upon which the shadow is being cast.

What we do not see in the ***shadows*** *is the ever-present residue of reflected light with its slow-varying profile and its complex mixture of multiple wavelengths.*[3] *We cannot because it has been removed by the systems that mediate* ***colour constancy****. An analogous story applies to* ***highlights****, which, despite the fact that they are always reflections, tend to be perceived as achromatic white.*

The achromatic appearance of cast shadows is reflected in how artists set about painting them between the Italian Renaissance and the second half of the Nineteenth Century. During this period, with few exceptions, they were represented by adding black or grey to the colour of the surface upon which they fell. It was not until the Impressionists and, above all, Seurat that artists began systematically to introduce multiple pigment-colours to represent the invisible residue of the reflected light. They did so for purely theoretical reasons not because they had learnt to see shadows differently to their predecessors.

Once we accept that regions of shadow are treated by the eye/brain in the same way as regions of body-colour, we realise that the law of colour-contrast must also apply to them and, consequently, that their presence will distort lightness space. This is why they have caused artists so many problems with respect to whole-field lightness relativities. On the positive side they provide an opportunity for learning more about the ramifications of colour contrast phenomena as they apply to the practice of drawing and painting.

Cast shadows

As explained in the *Introductory*, the *simultaneous contrast* phenomenon that creates the illusory gradations seen in Mac Bands also affects the appearance of cast shadows, which is one of the two main reasons why they give artists so much trouble.[4]

Figure 1 helps us to see why.[5] Notice that the shadow on the road gets darker

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3 *"What Scientist can Learn From Artists", Chapter 15*

4 The other, namely the problem of deciding what pigment colours should be used for representing this residual reflected light, is explained in depth in "*Painting with Light*".

5 It is important to emphasise that, if this was the actual scene rather than a photograph, the perceptual effects to be discussed would be considerably enhanced. One reason why is that, in the real world, the intensity differences between the illuminated and the shaded areas would be significantly greater. Another is that when moving focus from the far edge of the shadow to the shaded region in the near foreground, the eyes would have to travel a great deal further.

with increases in viewing distance. This is because the *lightness contrast* effect which is causing them is stronger where the edges are clean cut and weaker where they are fuzzy.

Figure 1 : Shadows on a street

Figure 2 : Shadow samples: (a) from far to near and (b) from left to right.

Notice also how different the triangle of shadow in the bottom left hand corner looks if, by focusing down on it, you can manage to remove the influence of the contrast with the adjacent sun-illuminated part of the road, Instead of the *Mach Band* type gradation from darker to the right and lighter to the left,[6] the shaded area approaches being equal lightness. *Figure 2* illustrates this by showing

6 And do not forget that the *Mach Band* like lightness gradations would be more dramatic in real-world viewing conditions than in a photographic image.

the uniformity of two samples from the interior of the shadow in the photograph.

Now imagine what would happen if the sun went behind the clouds. Although everything in the scene would be less strongly illuminated, the shaded parts of the road would now appear as being much lighter and less rapidly graduated. Clearly, both the seeming darkness of the shadow in *Figure 1* and the gradation across it are creations of the eye/brain.

Shadows and viewing distance

Figure 3 : Shadows getting darker with distance

Figure 3 shows the shadows of the canopies of the trees that line the esplanade at Castelnau de Montmiral becoming progressive darker as they recede into the distance.[7] The reason why they do so can be explained in four steps:

1. Light is diffracted by the edge of objects.
2. The diffraction causes the edges of the shadows of objects to be blurred.
3. The degree of blurring varies with the distance between the edge and its

7 As with the phenomenon *Figure 2*, this phenomenon is certain to be more marked in the real world than in the photographic illustration.

shadow and the nature of the light source(s).

4. Because the eye has limited powers of resolution, the degree of blurring that we see at the edges of shadows varies with the distance between the viewer and the shadow, according to the rule that the blurring is easier to see from nearer and more difficult to see from further. This is why the more distant shadows in *Figure 3* are perceived as having harder edges.
5. Since we already know that the harder the edge, the more powerful the simultaneous lightness contrast effect, it follows that the perceived difference between the shadows and their surrounds is accentuated with increases in viewing distance. This is why the nearer shadows in *Figure 3* are greyer and the more distant ones are blacker.

The temptation to make a ***rule*** that cast shadows regularly appear as darker due to increases in viewing distance should be resisted for at least three good reasons:

1. That all shadow-casting edges are not at the same distance from the ground, a variable that has an important effect on the fuzziness the edges of shadows and, therefore, their darkness.
2. That the surfaces upon which the shadows fall can vary in reflectivity.
3. The influence of secondary light-sources on the darkness of shadows can be important. For example, light reflected onto a cast shadow from a nearby, brightly illuminated large white wall will have an enormously greater effect on its lightness than will have light coming from a regions that is small, distant, dimly illuminated and dull in colour.

In short, when we look at nature, we realise that the variables are so numerous that we cannot be expected to be able to pin down their contribution to the final perception.[8]

As just indicated, where light-blocking objects are at different distances from the ground, the sharpness of the edges of the shadows will vary accordingly. *Figure 1* provides a good example. The old man is much closer to the ground than the roofs that are responsible for the shadow adjacent to him. Consequently the edges of his shadow are much less blurred than the edges of theirs. Indeed, since the distance between him and the ground allows little room for visible effects of diffraction, the entire outline of his shadow is sharply defined. It is for this reason

8 *Chapter 4* in which are found quotations from *early Modernist Painters* concerning the lack of reliability of the rules.

that it appears to be very much darker than the adjacent, lighter-seeming shadow of the house, even though the light reflecting from both must be similar.

Shadows of vertical objects

Figure 4 : Photograph of a man's shadow

Figure 5 : Samples from Figure 4 - left near to head, right near to feet

Figure 4 shows the shadow of different man. This time the sun is shining from directly behind him, at an angle that makes his shadow much longer. Its edges exhibits a range of degrees of fuzziness, with the nearest parts being the fuzziest and the furthest, the most clearly defined.

All this means that *Figure 4* provides a good demonstration of two of the factors that explain the progressively darkening shadow on the esplanade in *Figure 3*. It shows that the perceived darkness of shadows is strongly influenced by:

1. The distance between the shadow-making object and the shadow it is making.
2. The degree of fuzziness of their edges.

Thus, the edges of the shadows of the man's feet are very clean cut while those of the head are blurred. In between the shadow become progressively less clean cut and more blurred. The influence of the ***simultaneous lightness contrast effect*** ensures that the edges of the shadow reflect these changes. They are very dark where they are adjacent to the feet and progressively less so as they moves towards the head.

Figure 5, shows that, contrary to appearances, when isolated from their context, the lightness of the two parts of the shadows that seem most different in *Figure 4* are very similar.

The photos in *Figures 6, 7* and *8* provide more information on the appearance of shadows. All three show the same shadow of the same power-cable-carrying post. All were taken in the time it takes to hurry across a narrow road and focus a camera as quickly as possible. Although this means that their actual reflectivity is virtually identical, their appearance is clearly very different. Why is this so? Why does the shadow in *Figure 6* have hard edges and look the darkest? Why does the shadow in *Figure 7* have softer edges and look less dark? And why does the shadow in *Figure 8*, have the softest edges and look the least dark?

Although one of the factors that contributed to the appearance of the images in the three figures was the automatic lightness related adaptations of the camera, you will have to take it on trust that on the whole these seem to have resulted in a reduction rather than an exaggeration in the differences as they appeared to my human eye. For example, when, after looking at the other two shadows, I turned my gaze downwards towards the shadow illustrated in *Figure 8*. I could hardly believe how pale and insubstantial it seemed to be. Indeed, for a fraction of a moment, I thought that it had disappeared.

Figure 6 : Shadow of a post (1) - Sun behind viewer

Figure 7 : Shadow of a post (2) - Sun in front of viewer

Figure 8 : Shadow of a post (3) - Looking down from above

In *Figure 7*, it is clear that, like the man's shadow in *Figure 4*, the edge appears to get more and more fuzzy as it gets nearer to us. This progression is due to a combination of the gradual increase in the gap between the post and the ground and the effects of *diffraction* (the process by which a beam of light is spread out as a result of passing through an aperture or across an edge). The physical reality in *Figure 6* is the same, but due to the limits on the resolving powers of the eye (or camera lens), the edge appears to be hard all along the length of the shadow. This can be explained in the same way as the progressive darkness of the shadows on the Esplanade in *Figure 3*: namely according to the rule stating that the further away an edge, the less optically resolved and, consequently, the sharper the it will appear to be. The upshot is that whereas in *Figure 6* the shadow looks equally dark along its whole length, in *Figure 7* the shadow looks progressively lighter as it nears the viewer. Since in *Figure 8*, the edge seems to be almost dissolving, the shadow in it is perceived as being the least dark of the three.

How should artists respond to a situation in which, although we see each shadow as distinctly different, a light-meter measuring the amount of light being reflected from them will give identical readings for all three? Do they paint (a) what they experience ("*experienced reality*"), (b) what the light-meter tells them ("*measured reality*") or (c) some compromise between the two?

Any reasoned answer to these three questions will raise fundamental issues in painting. It is also likely to come to the conclusion[9] reached by artists over the centuries that have passed since the *Italian Renaissance*, namely that some kind of compromise will be required.

Whatever compromise chosen, the artists will have had to confront the conundrum that faces us all. If we insist on depicting "*what the see"*, the result will be unrealistic, but if we stick to "*measured reality",* it will not look right. This being the case focus must be on the solution that works best in terms of the painting in hand. Whatever this may be we can be sure that finding that it will:

- Need to take whole-field lightness relations into account.
- Require a process of trial and error.

There is no alternative.

Inside-outside

Figure 9 shows the bars of a white-painted window seen from the inside of a room with white-painted walls. Since, from the viewers' point of perspective, the amount of light reflecting back from thee bars is far less than those deriving from the sky or from the sun-illuminated landscape outside, a particularly strong simultaneous-lightness contrast effect occurs. It causes the white-painted window bars and frame to be seen as a deep black.

In the photograph, all that can be seen of the white-painted walls is just as black. However, people situated in the actual room would find that as they moved their eyes away from the window bars, they would adapt to the locally lower-level lighting conditions. Consequently, they would see the walls as being lighter. If they were able to move their eyes to a position where they were no longer consciously aware of the light coming in at the window, the colour of the hitherto black-looking, white- painted wall would actually appear as white.

Clearly the situation is full of ambiguity and the question that naturally arises is, "*What colour should artists use in these circumstances?*" Should it correspond to the *black-seeming* white-painted window bars or the *white-seeming*, white-painted walls?

9 As evidenced in their work.

Figure 9 : White-painted window frame against daylight

The first alternative means the artists opting for the *chiaroscuro* effect beloved of Rembrandt. Any approach that produces so many masterpieces cannot be wrong, but it does have its limitations. What if the artists feel uncomfortable with using black paint to represent white-painted walls which they actually experience as white?

The second alternative is for artists to aim at representing "*their experienced reality*". If so they need to paint the white walls as being "*white*". The problem will come when they return their attention to the black-seeming window-bars. This will no longer provide the illusion of a black stimulated by a lightness contrast effect. Instead it will look like what it is, namely black-painted window bars. And how do they deal with the transition between the white wall and the back window bars?

Experienced reality

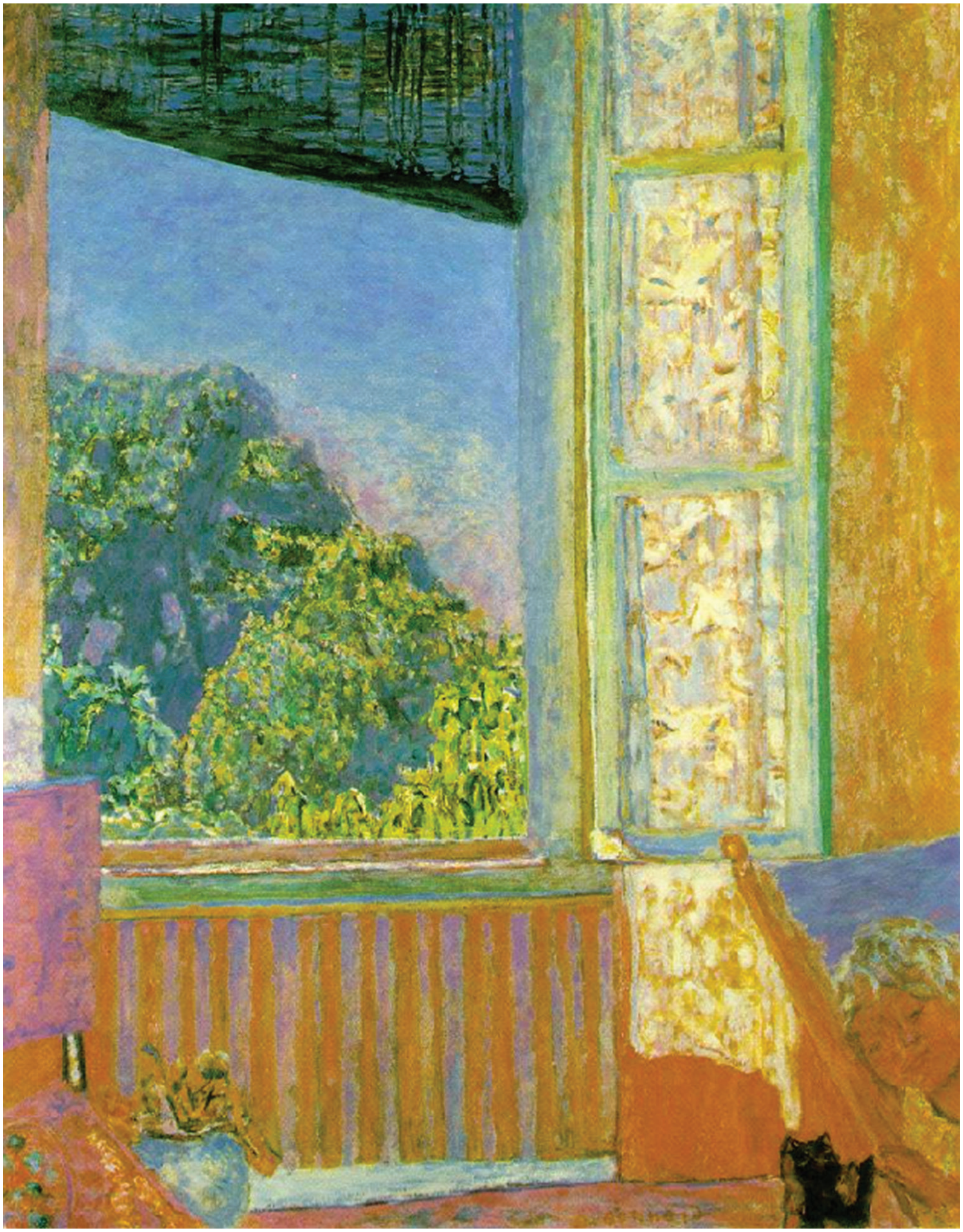

Figure 10 : Pierre Bonnard-interior with window

As repeatedly emphasised above, when the early *Modernists Painters* began grappling with the idea of painting “experienced realities”, they had to face the difficulties arising from the considerable differences between the experience provided by their constantly adapting eyes and the much more static *measured reality* that their predecessors had favoured.[10]

Of the many things that excited them about experienced reality, there was one above all that influenced the future use of colour in painting. The discovery that their eye/brains constantly adapting to local light-intensity levels, such that the lightness range within their visual world is regularly squashed.

This was an important part of the revolution initiated by Van Gogh, Gauguin and Toulouse-Lautrec and exploited to such good effect by the Fauves, the German expressionists, the older Monet, Matisse, Bonnard (as illustrated in *Figure 10)*. It was also the start of the process that led Michael Kidner to impress on the students who attended his colour course, that colour intensity and colour interactions are maximised in equal lightness paintings. Largely, as a result of the new approach, paintings became brighter and more colourful.

Gilchrist

This chapter on *cast shadows* would no be complete without reference to the experiments of Alan Gilchrist which provide particularly powerful demonstrations of ways in which the physical context in which surfaces are seen can change their perceived lightness. They show that by tricking the eye/brain into believing that a surface is *horizontal* when it is actually *vertical* (by using one eye instead of two) or that it is *far* when it is actually *near* (by clever use of overlap cues), it can be made to appear as alternatively “*white*” or “*black*”. True, his demonstrations had all the advantages of using a laboratory set-up where everything could be arranged to maximise the researched effect and that in real world conditions it is unlikely that such spectacular changes will be encountered. However, this does not mean that the variables which he was studying will not have an effect on appearances. Quite the contrary: Both shutting or opening an eye and changing the contextual framework in which they are seen can change colours significantly.

Seeing blue and other colours in cast-shadows

None of the above is meant to suggest that there are not occasions when normal sighted people will see *reflected-colours* and/or *induced-colo*urs in shadows.

10 Which the early *Modernist Painters* saw as being exemplified by the photograph..

Indeed, they will regularly see them when the colour-constancy system breaks down. So under what circumstances does this happen? A natural starting point is research into where the how-to-do-it books get their ideas from. If we do so, what we find is that, like so many colour related subjects, we are taken back to the *Nineteenth Century* scientific literature on the perception of *cast-shadow*s. Thus, in 1839, the German physiologist, Müller wrote:

> "*Coloured shadows are usually ascribed to the physiological influence of contrast; with the complementary colour being presented by the shadow being regarded as the effect of internal causes acting on that part of the retina, and not on the impression of coloured rays from without. This explanation is the one adopted by Rumford, Goethe, Grotthuss, Brandes, Tourtual, Pohlmann, and most authors who have studied the subject.*"[11]

However, a clear lesson to be drawn from Land's *colour constancy demonstration* is that perceptions of the kind that Müller is referring to are only perceived *under certain conditions*. It also makes clear that, on all occasions when these occur, *everyone will see them*.

Land's demonstration also shows that the *colour-constancy system* cannot operate unless there is sufficient information in the scene being analysed. It breaks down whenever the region of colour being analysed is *without a multicoloured context*. For example, everyone will see the shadow of the object illuminated solely by red light as an induced green.[12] Likewise, everyone will see the blue of the sky reflected in the cast-shadows of trees in snow-covered (that is to say, achromatic) landscapes. However, in most natural scenes, the range of colours entering the eye favours the operation of the colour-constancy system. As a result, on most occasions, cast-shadows will appear to be relatively dark and drained of specific hues. If we paint what we see, we will find ourselves mixing colours with black or grey paint to represent shadows.

One conclusion that can be drawn from all this is that the early *Impressionists* were unlikely to have been able to see the blues and violets which they sometimes painted into their shadows. Even more certainly, the multicoloured *Pointillist* shadows of Seurat and his followers could not have been based on observation. It is inconceivable that any of these artists would have had eye/brain

11 Müller, J., 1839, Elements of Physiology (English Translation by Baly).

12 As was demonstrated experimentally in the *Eighteenth century* by Gaspard Monge, as described in *Vol..1, Chapter 10.*

systems that work on different principles to those of everyone else. Accordingly, it can be assumed that, when choosing the colours to use, they were *blindly following theory*. It was only after *La Grande Jatte* that the four crucial advantages of complex-coloured shadows became evident. To recap, these were the:

1. Added realism.
2. Richness of colouration (which could be enjoyed for its own sake).
3. Creation of fascinating optical effects when viewed from close-up.
4. Resolution of the long-standing problem of shadows looking like holes in the picture surface or patches of colour on the picture plane, separated from the objects within the illusory space being depicted.

Implications

This chapter and the previous one have focussed on ways in which induced colour phenomena influence the way we see Mach Band effects in nature and cast shadows and in doing so have highlighted some of the consequent problems for artists As we will see, similar difficulties apply to shading, the subject of the next chapter. For this reason it seems appropriate to leave our summing up of implications until later. For the time being suffice it to say that the visual world in which we live is fascinating and artists can benefit from spending time trying to understand what is happening and why. Although doing so will reveal all sorts of issues, it will put them in a position to choose which compromises are most likely to suit their objectives.