ARCHITECTS MEMO
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shepherd's delight

During the recent Australian bushfires, the malevolence and horror of the catastrophe was often reflected by the lurid sunsets which we experienced on this side of the Tasman. Asked about the optical reasons for this I saved myself from the embarrassment of spouting nonsense before my brain was fully engaged and decided to do a little more research first - thankfully!

Viewed from space, our sun appears white, as do most other stars, and our atmosphere appears black - so where do spectacular sunset (and sunrise) colours come from? To answer this, we need to understand a little of the atmosphere and of our sunlight.

Our atmosphere is made up of five different levels reaching a thickness of around 500 kilometres although the bulk of it is contained within the bottom 16 kilometres. This includes the troposphere, which ranges between 7-20 kilometres and the stratosphere, which extends from the troposphere out to about 50 kilometres from the earth's surface. In the lower part of the troposphere is another division of a thickness, which varies with atmospheric conditions, called the boundary layer which, importantly for our story, contains most of the atmosphere's dust and haze.

As one moves upwards from the troposphere through the stratosphere the air gets thinner and thinner, on average about 1,000 times thinner than at sea level, and clearer and clearer.

This boundary layer contains the majority of the atmosphere's pollutants, as well as the lower cloud formations. Some very fine pollutants, such as some of the finer smokes and aerosols, can rise into the upper levels of the troposphere, as can some cloud formations, such as cirrus and altocumulus layers. Even the stratosphere holds some pollutant particles, almost solely derived from volcanoes and in the form of fine dusts of sulphuric acid aerosols.

Visible light from our sun is a form of electromagnetic energy ranging across the wavelengths of roughly 400-700 nanometres. This light interacts with a wide range of objects as we all know but some of the most interesting are the interactions with very small objects, even down to individual molecules of gas. Omitting absorption, the various interactions are known collectively and descriptively as scattering with, as if it were not complicated enough, two different mechanisms operating depending on the size of the object with which the light interacts!

If the object is very small compared to the wavelength of light (such as a molecule of oxygen) the scattering is governed by Rayleigh's Law, which says that the scattering will be random and inversely proportional to the fourth power of the wavelength! This means that blue light gets scattered truckloads more than red light. All this scattered blue light bounces around the sky, eventually reaching our eyes and telling us that the sky is blue. The red light takes a much straighter, more penetrative path and, in full daylight, does not dominate. Incidentally, violet light gets scattered even more than blue but our eyes are just not very efficient at picking up violet!

Those lowdown pollutants hanging about in the boundary layer, along with whatever cloud may be there, are about 1,000 times bigger than oxygen molecules. Their range of sizes pretty much matches the range of wavelengths in visible light - not dissimilar to the prime pigments that we use in paint. These particles are covered by Mie scattering, which is different, being relatively unaffected by changes in wavelength and tending to scatter along the direction of the incoming light rather than the random Rayleigh. There is also a significantly higher level of absorption with particles in this size range thus attenuating the amount of light that the eye receives.

continued overleaf...

So, what happens when the sun sets (at last, we are getting to it - I hear you cry)? As the earth turns, the sun sets lower in the sky and the light, coming from lower and lower angles, must traverse ever thicker layers of atmosphere. The atmospheric travel path at the horizon is forty times that of when the sun is overhead. If one was out in the middle of the ocean on a clear late afternoon one would notice the sun taking on a redder aspect as all of those skittery blue waves have expended themselves, via multiple scatterings through their (now) much longer travel path, leaving the field to the slower, straighter red waves. High clouds catch, then throw back to us, these last red/orange rays in what can be dizzyingly displays of beauty. Even after the sun dips below the horizon, the atmosphere acts as a giant lens, which refracts low sunset rays into long curved paths, highlighting the high tropospheric and stratospheric particles to give a final scintillating display before all the light goes.

Back on the polluted land, the light must battle its way through the boundary layer which, at the time of the bushfires, was heavily laden with smoke, dust and aerosols. As well as the loss of the blue light, absorptions of the other wavelengths mute the overall effect, distorting the bright orange/reds into more sulphurous yellow ochres and pinkish shades - very Dante-esque!. As the sun drops further below the horizon, the bending effect referred to above comes into play allowing the rays to travel through the unsullied higher layers, restoring, once again, the final brilliant roseate glow.

Light and colour are inextricable! A fine winter's day in Northern Europe receives about 600 watts of illuminance per square metre which, because of the declension of the sun at that time, is deficient in blue/violet waves. Compare that to the tropics which receive on average 1,400 watts per square metre with its full complement of blue/violet. Of course, colours are going to look very different in these locations and conditions! While tempting to pick up the latest fashion colours from Europe, they just don't react well to our local natural lighting. Instead colour selections are drawn to more weathered and nature inspired hues that comfortably embrace the bright light.

Food stores are well aware of the effect of light on the appearance of their merchandise. Red meat and colourful fruits and vegetables appear much more appetising under a warm white light of around 3,000 Kelvin while fish and green vegetables look much more inviting under a cool white light of around 4,500 Kelvin. Jewellers know a thing or two also, displaying gold under a warm white light while getting extra, totally irresistible sparkle from their diamonds using lighting of up to 5,000 Kelvin!

Finally, it is well known by those versed in the art that colours can be matched using pigments and pigment ratios, which differ somewhat from those used to achieve the original target colour. The weakness is, however, that such a match will only be accurate under the exact same lighting conditions in which the match was made. Change the light source and those small differences in the composition of the colour match interact differently with the spectrum of the new light source and the colour no longer matches. This phenomenon reveals itself when matching paints to colour cards and when attempting to replicate a company's colours using a different colour system. Colour matches can only be completely free of this metamerism if they are produced from exactly the same colour and tinter system as the original colour.

I shall return to this topic if anything further comes to light - boom, boom!