Master of colour

Did a 13th-century English bishop understand what makes our world such a gaudy place, asks Michael Brooks

MODERN science has a simple story. It began in the Renaissance with the revolutionary observations of Copernicus and Galileo, and flowered in the Age of Enlightenment with Robert Boyle's meticulous chemical experiments and Isaac Newton's ordering of the clockwork cosmos.

That picture is so commonplace that we risk being hoodwinked by it, says physicist Tom McLeish of the University of Durham, UK. "So much coffee-book history represents science as an Enlightenment phenomenon, and everything before as mystical alchemy and darkness," he says. McLeish is part of the "Ordered Universe" collaboration, a grouping of scientists and historians based at Durham that is gathering evidence for a different story.

Now they have a star witness for their case – Robert Grosseteste, a 13th-century English churchman and scholar who ended up as bishop of Lincoln. Grosseteste has long been seen as a pre-Renaissance Renaissance man, who wrote about everything from sound to comets and stars. But it is an essay on the nature of colour, written in about 1225, that has the Durham researchers most excited. They believe it shows that Grosseteste had a very modern understanding of colour. If so, the Dark Ages may not have been so dark after all.

Colour is a difficult concept to pin down. How does the infinite array of hues between black and white arise? For Aristotle, they were radiated from an object. Seven "species" of colour lay on a single line linking black and white, and all the others were made by combining these species in different ways.

Today, we know that an object's colour depends on the light frequencies it absorbs and reflects. Colour occupies not a line, but a three-dimensional space – three because our retina has three types of light-sensitive cone cells tuned to different frequency ranges. This "trichromatic" colour vision allows graphic designers, television sets and computer screens to create millions of colours using just three frequencies of light – generally red, green and blue.

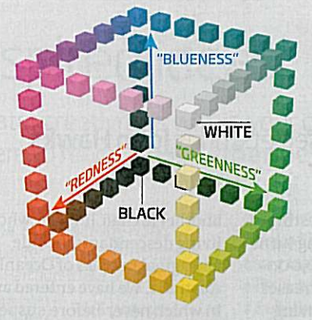
There are other ways of mapping out the complete colour palette. Some of these schemes do not work by mixing specific colours: for example, one way is to vary lightness, hue and saturation (see diagrams, right). But three independent variables are always needed to produce the gamut of colours we see.

All of this seems to have been clear to Bishop Grosseteste. Born around 1175 in the county of Suffolk in eastern England, by the 1220s he was teaching theology at Oxford. Grosseteste set down his colour theory in just 400 words of Latin, with no mathematics or diagrams. "It's an incredibly dense piece of writing," says historian Giles Gasper, who leads the Ordered Universe group.

It is also a significant break from

"Colour is a difficult concept to pin down: what makes the infinite array of hues we see?"

previous thought. First, Grosseteste says, colours do not exist by themselves, but are a property of the interactions of light and matter: "Colour is light incorporated in a diaphanous medium," as he puts it. Second, colours are made by sliding along three scales: from *clara* to *obscura*; from *multa* to *pauca*; and from *purum* to *impurum*. Whiteness, he adds, is an extreme produced by the combination of *clara*, *multa* and *purum*. This



Television and computer screens build up the full palette of colours using the three "dimensions" of red, green and blue

description is very similar to the way we regard colour today. "At the conceptual level Grosseteste's writings show a very strong resonance with modern views of colour," says Hannah Smithson, a perceptional psychologist at the University of Oxford and a member of the Ordered Universe team.

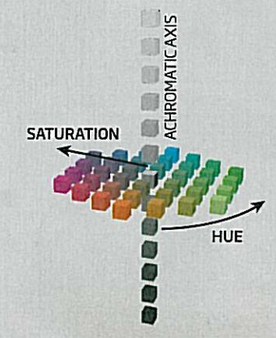
It is difficult to assess the bishop's ideas more rigorously as he does not define his terms precisely. A Latin-English dictionary might give "clear", "dark", "much", "little", "pure" and "impure" as translations, but how would these match up with modern ways of specifying colour? "We've had guesses: we talked about whether the dimensions he's talking about are lightness, or something corresponding to saturation or hue, for example," says Smithson. "But it's not easy to find a very satisfactory mapping."

The team is convinced there is more to Grosseteste than just guesswork. Scholars had largely dismissed the text on colour because of two basic errors. First, working out how colours can be combined, he gets a key number wrong, coming up with nine when the correct figure is 14. Second, if white is *clara*, *multa* and *purum*, black should be its polar opposite: *obscura*, *pauca* and *impurum*. Grosseteste, though, has it down as just *obscura* and *pauca*.

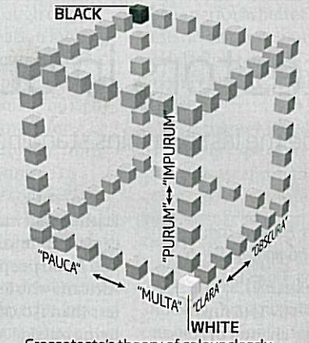
It turns out Grosseteste was simply the victim of bad editing. For unknown reasons, historians have been working with late copies of his manuscripts. When Gasper consulted an early version at the University of Oxford's Bodleian Library, he found a "14" in the correct place, written in Arabic numerals. That shows Grosseteste was abreast of the latest mathematical developments: Arabic numerals only reached Europe in 1202 with the publication of *Liber Abaci*, a treatise by the Italian mathematician Fibonacci. They were still unfamiliar to Grosseteste's later transcriber, who interpreted 14 as IX in Roman numerals and wrote "*novem*", the Latin for nine.

To investigate the other stain on Grosseteste's reputation, Gasper had to travel to the National Library of Spain in Madrid to seek out the earliest surviving version of the manuscript. "I was heart in mouth, hoping it would work out," says McLeish. And it did. There, in the description of blackness, was the missing *impurum* – the final proof, think the researchers, that Grosseteste worked as meticulously and methodically, and with just as sure a grasp of mathematical logic, as any true scientist after him (*Journal of the Optical Society of America A*, vol 29, p 346).

Gasper believes it is not just the presumed errors that have made us overlook Grosseteste's abilities, but also the fact that he did not present his conclusions in a way that looks



Another 3D depiction of the palette uses an "achromatic" axis from white to black, plus a plane where hue varies around the axis and saturation increases with distance from it



Grosseteste's theory of colour clearly implies a cubic colour space with white and black at diagonally opposite corners, but other details remain obscure

"scientific" to our eyes. "One of the things that struck me working with scientists on the project is how much medieval thinking is absolutely shot through with mathematics," he says. "It really does underpin quite a lot of what they do, but because it's not presented in formulae you almost miss it."

The next step will be to revisit Grosseteste's other writings. Our interpretations of them are also based on late editions of his manuscripts, and Gasper, McLeish and the team are keen to see what else might have been overlooked or misinterpreted.

It is early days, but for Gasper the historian, we already need to recolour our conceptions of the medieval capacity for scientific thought. "This is a society thinking about how you order society, and how you order the heavens," he says. "Grosseteste is doing science; he is puzzling out his interpretation of the universe," he says.

For McLeish the physicist, a rethink could have a positive influence on how we view science: not as a recent, rarefied innovation, but as something deeply human and deeply old. "Grosseteste is, in a sense, our brother or our ancestor," he says. "I feel as if I could sit down with him and chat over a glass of mead." ■

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