FIG. 2 Structures of some non-standard base pairs. *a* iso-C:iso-G. *b* κ : χ . *c* κ : π .

iso-C:iso-G base pair (Fig. 2*a*) and the other base pairs formed by κ with χ (Fig. 2*b*) or with an equivalent purine nucleoside analogue π (Fig. 2*c*) that is more readily incorporated into oligodeoxynucleotides by non-enzymatic synthesis.

The idea of a third base pair involving iso-G and iso-C is not entirely new². Benner and his co-workers previously showed that oligonucleotides containing these bases can be copied enzymatically³. However, as had been feared, the fidelity of copying was poor, perhaps because iso-G can exist in a tautomeric form that pairs with U. Now it has been shown that base pairs formed by κ with χ or with π do not suffer from this deficiency. Oligodeoxynucleotides containing κ and π were synthesized by chemical methods and shown to form helices almost as stable as those formed by oligomers containing only the standard base pairs. Next, it was confirmed that mispairing involving κ and π destabilizes these helices to about the same extent as mispairing involving the standard nucleotides.

DNA and RNA polymerases, it seems, are sensitive only to the external geometry of a base pair and indifferent to the arrangement of hydrogen bonds that maintains that geometry. Consequently, when the pyrimidine nucleotide analogue κ is incorporated into a template oligonucleotide, both T7 RNA polymerase and the Klenow fragment of DNA polymerase 1 will incorporate χ opposite it. The fidelity of replication using the DNA polymerase is good; no incorporation of dA or

The science of art appreciation

WHAT analytical chemistry has to offer the art historian is one of the themes of *Italian Painting Before 1400*, an exhibition currently on show in London*.

The San Pier Maggiore Altarpiece (below), a highlight of the exhibition, is one of the largest and best-documented works produced in Florence in the second half of the fourteenth century. Research on it typifies the way in which scientific analysis of artists' materials moves from mere description to explanations of the painting technique and of artistic effect. Several methods are used for identifying pigments. Among them are energy-dispersive X-ray microanalysis carried out in the scanning electron microscope, where it is possible to analyse selectively a single pigment particle; laser microspectral analysis, used on paint cross-sections and minute unmounted flakes; and X-ray diffraction analy-

Many of the organic dyestuffs used to make artists' pigments deteriorate and fade so seriously that their presence and effect is not always easily discernible. In particular, the yellow lake, known as *arzica*, which is found in the San Pier Maggiore Altarpiece and other works in the exhibition, has been identified only rarely before. *Arzica* was notorious for its impermanence, even in the fourteenth century, yet artists continued to use it, especially for mixed greens, a hue in which the mediaeval palette was particularly weak.

It was through the use of another technique, gas chromatography – mass spectrometry, that one of the most significant finds of the exhibition emerged: the remnants of an original fourteenth-century varnish on the edges of the Pentecost panel in the second tier of the altarpiece. The type of varnish applied to tempera

sis, for fairly pure samples of crystalline pigments.

When applied to the altarpiece, the techniques revealed the range of the palette and confirmed that the painter Jacopo di Cione, fulfilled the terms of his contract by using the best materials available. The finest grade of the most expensive pigment, ultramarine blue (lapis lazuli), was explicitly specified and was reserved for the Virgin's robe – for mediaeval artists there was an established link between materials and meaning, intrinsic value and aesthetic appreciation.

Rather more interesting, however, is the identification of a range of red and yellow organic 'lake' pigments, which do not feature in the contract and were widely used on the altarpiece both in colour mixtures and as final glazes.

paintings and its visual effect is a subject much debated among both restorers and art historians. Tiny patches of a transparent orange substance were found directly overlying original paint, and these were identified as a sandarac-type resin dissolved in linseed oil, heat-bodied by boiling, with the addition of red lead to act as a drier. The components correspond with contemporary varnish recipes. As the catalogue accompanying the exhibition points out, our view of the original surface appearance should be reconsidered in the light of this discovery – the resin would produce a viscous and glossy varnish coating, which would also saturate the colours in a manner quite alien to current interpretations of how these paintings were intended to look.

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**Italian Painting Before 1400*, sponsored by Esso, is at the National Gallery, Trafalgar Square, London, until 28 February.

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