the conversion process is not fully understood. Remodelling of chromatin (DNA–protein complexes), which in turn affects gene expression, seems to have a central role. Yoo *et al.*[3] report that the two miRNAs modify the composition of the BAF chromatin-remodelling complex by regulating expression of its subunits, thereby transforming it into a chromatin remodeller that is characteristic of differentiated neurons[9]. But it remains unclear whether the specific chromatin structure in the converted neurons is the same as that in primary neurons.

In this respect, Caiazzo and colleagues' data[2] are informative. They show that the gene-expression profiles of the dopaminergic neurons generated and those of isolated mouse midbrain dopaminergic neurons are similar but distinct: about 160 genes were expressed differently, with a more than fivefold variation in expression. This indicates that functional similarity of the converted neurons does not necessarily correspond to similar chromatin structure or gene-expression levels, and so cautions against the cells' premature clinical use. Instead, the differences between the converted neurons and their corresponding primary neurons must be characterized, and whether they give rise to unwanted side effects should be explored.

The miRNAs used by Yoo and co-workers[3] probably also affect the expression of other proteins involved in cell-fate switching and neuron differentiation, including components of other chromatin-remodelling complexes. So before the clinical use of converted cells can be contemplated, further work should determine how the various chromatin-remodelling factors, and other factors that affect gene expression, contribute to cell conversion and how they can be controlled. Another question to be addressed is how the similarities and differences between converted cells and primary neurons, in terms of gene expression and chromatin structure, correlate with the functionality of the converted neurons — with their neurotransmitter production, firing of action potentials and functional integration into neuronal networks. It is also not known how gene expression and chromatin structure are shaped by intrinsic mechanisms and by the cells' immediate environment, in particular after their transplantation.

Thus, an area for further exploration is how a diseased brain's environment influences the functionality and gene-expression profiles of the transplanted converted neurons. Whether the converted cells are transplanted into the supportive environment of a neonatal mouse brain or into a diseased or aged human brain probably makes a difference. The finding that DNA methylation is dynamic in postnatal neurons[10] raises hopes that the environment into which these converted cells are transferred could contribute to correctly shaping their gene-expression profile for long-term integration and function. However, the diseased brain in aged humans might not be so good at doing this. Therefore, investigating strategies to compensate for this deficit is perhaps the next big challenge in developing cell-based therapies for neurodegenerative disorders. ■

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X-RAY IMAGING

The chemistry inside

To understand the properties of many useful materials, the chemical structures that form within them from elements of low relative atomic mass must be determined. A new X-ray imaging technique does just that.

CHRISTIAN G. SCHROER

One of the most striking properties of X-rays is their ability to penetrate matter. In fact, X-rays are partially absorbed as they pass through an object, and cast a 'shadow' of the structures inside — an effect that underpins medical X-ray imaging. As objects become bigger, harder (more energetic) X-rays are needed to penetrate them. The problem is that the harder the X-rays, the smaller the imaging contrast for light elements — those that have low relative atomic masses, such as carbon, nitrogen and oxygen.

Reporting in *Nature Materials*, Huotari *et al.*[1] now describe a way of using hard X-rays to make three-dimensional images of objects that also detects light elements with high sensitivity. The technique even distinguishes between different bonding modes of those elements, and should enable studies of the interiors of diverse objects, such as biological systems, working catalytic reactors and fuel cells.

When a crimson rose is illuminated by sunlight, it appears red to us even though the light contains all the colours of the rainbow. This is because the different colours in the light are absorbed and scattered differently

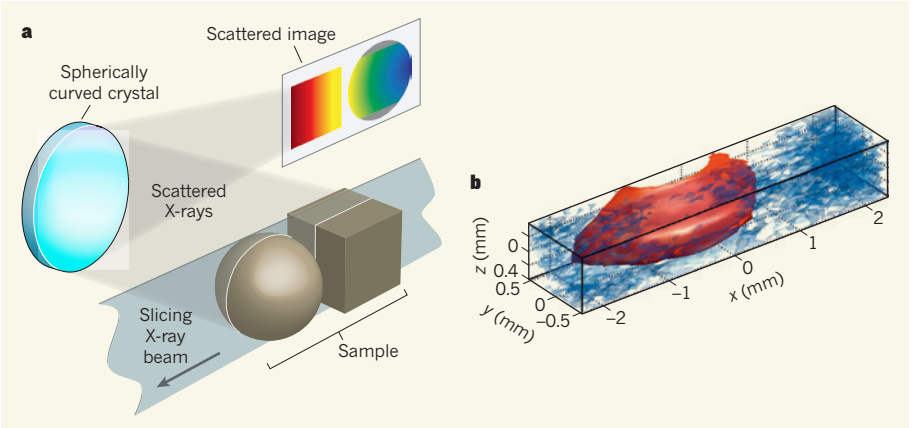

Figure 1 | X-ray scattering for three-dimensional imaging. **a**, Huotari *et al.*[1] report a technique for imaging samples of materials that contain light elements such as carbon, nitrogen and oxygen. A cross-section of a sample is illuminated by a monochromatic, two-dimensional X-ray beam. X-ray scattering occurs, which can alter the energy of the scattered X-rays. A spherically curved crystal filters the scattered X-rays by reflecting only those of a certain pre-set energy, and focuses them onto a detector to form an image of the cross-section. Three-dimensional images are obtained by scanning samples through the incident beam. **b**, The authors' technique can distinguish between different chemical bonding modes in samples. This image shows part of a sample in which a diamond is encased by graphite. Regions containing diamond carbon atoms are shown in red, and those containing graphite carbon atoms are in blue. (Figure adapted from ref. 1.)

by molecules in the petals, which effectively reflect only the red part of the spectrum. Modern spectroscopic techniques make use of this effect to determine the chemical composition and structure of an object. In photoabsorption spectroscopy, visible or ultraviolet light, or X-rays of a given energy, are shone onto an object, and the amount of light absorbed is measured as the radiation passes through[2]. When the energy (colour) of the radiation is varied, the transmittance — a measure of the amount of light that passes through a sample — changes in a way that is characteristic of the atoms in the sample and their chemical bonds to neighbouring atoms. In this way, detailed information about the chemical environments in an object can be obtained.

Carbon, nitrogen and oxygen are particularly abundant in both natural and technologically relevant materials. In order to understand the properties of these materials, it is important to determine the diverse chemical structures that form within them. But to investigate these structures using photoabsorption spectroscopy, for example, soft X-ray light must be used. Most materials are rather opaque to this part of the electromagnetic spectrum — even in water, soft X-rays travel the distance of less than a hair's breadth. It is therefore difficult to use this technique to investigate thicker materials such as biological tissues, or the chemistry in the vicinity of a battery electrode. Analogous electron-based spectroscopic methods could in principle also be used, but electrons penetrate even less deeply into materials than do soft X-rays.

Huotari *et al.*[1] have addressed these difficulties by using hard X-rays, which easily penetrate large sample volumes and a variety of specialized sample environments. In particular, they have used hard X-rays in a technique called inelastic X-ray scattering spectroscopy[3]. In their system, a sample is partly illuminated by a sheet-like, hard-X-ray beam of fixed energy (Fig. 1a). The X-rays are scattered by the atomic structures in the illuminated slice of the sample. The scattered X-ray light is then reflected by a spherically curved crystal, which focuses a two-dimensional image of the slice onto a detector. Three-dimensional images are obtained by stepping a sample through the beam and assembling the two-dimensional images that are acquired at each step.

In addition to focusing images of samples onto the detector, the curved crystal has a second vital function: because its reflectivity is strongly selective, it reflects and images only scattered light of a certain energy onto the detector. For example, by setting up the system so that only light that has the same energy as the incident beam is reflected, an image can be formed using elastically scattered X-rays — those that are scattered without transferring part of their energy to the sample. Such an image depicts the static (time-averaged) structure of the sample. Similarly, the energy reflected by the crystal can be set to a given energy transfer (the difference in energy of incident and scattered X-rays). This allows imaging of inelastically scattered X-rays — those that transfer part of their energy to the sample, for example by exciting vibrations, valence electrons or collective motions of electrons.

Crucially for Huotari and colleagues, hard X-rays can also transfer energy to atoms of light elements in excitations similar to those that occur in photoabsorption spectroscopy. The resulting inelastic-scattering spectrum thus reveals the local chemical structure of those atoms in a material. So, by tuning the crystal in their experimental set-up to reflect scattered X-rays at transfer energies corresponding to such excitations, the authors could obtain images that reveal details of the chemical bonds of a given light element in samples.

To illustrate the strength of this approach, Huotari *et al.* analysed a test sample consisting of diamond enclosed by graphite — two allotropes of carbon in which the chemical bonding between atoms is different. Using their technique, the authors were able to map out clearly the positions of the different allotropes in the sample, effectively locating the diamond and graphite components on the basis of their bond structures (Fig. 1b). No other technique could do this, although the diamond could perhaps have been detected using classical absorption imaging because diamond is denser than graphite. But the classical approach would provide no information about the chemical structures of the allotropes.

Because inelastically scattered X-ray signals are typically weak, the authors' method requires the brightest available X-ray sources. This currently restricts the use of the technique to researchers with access to modern synchrotron radiation sources. Another limitation is the spatial resolution of the technique — the authors studied millimetre-sized samples, but it would be desirable to use the method to study microscopic samples.

Nevertheless, the ability to characterize the chemical bonding of light elements inside thick samples, and of samples in specialized environments (such as in chemical reactors or pressurized cells) opens up many applications. For example, one could use the authors' method to visualize local bond structure in composite materials, or to identify different phases in polymer blends. It could also be used to study the reactions of carbon and oxygen in industrially useful catalytic reactions, such as the catalytic partial oxidation of methane[4] — one of the steps involved in the conversion of natural gas into liquid fuels. ■

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GLOBAL CHANGE

The grass response

A three-year study provides insights into how the productivity of a semi-arid rangeland, containing grasses using different photosynthetic pathways, will change in a warmer world with more atmospheric carbon dioxide. SEE LETTER P.202

DENNIS BALDOCCHI

The grasses that provide forage for most of the world's livestock use either the C_3 or the C_4 photosynthetic routes to fix carbon dioxide into carbohydrates. Both routes eventually employ the carbon-fixing enzyme ribulose bisphosphate carboxylase. However, C_4 grasses are more efficient photosynthesizers as a result of their distinct morphology and their use of another enzyme, PeP-carboxylase, before this ultimate step of carbon fixation. On page 202 of this issue, Morgan *et al.*[1] describe experiments aimed at assessing the effects on mixed C_3/C_4 grasslands of raised levels of atmospheric CO_2 and higher temperatures, and, crucially, how these conditions might change the plants' water budgets.

As any high-school science student or climate-change sceptic knows, CO_2 is food for plants. So the presumption that 'more is better', as we release CO_2 at an undiminished rate from fossil-fuel combustion, is partly true. This effect occurs because photosynthesis is stimulated when leaves are exposed to above-ambient levels of CO_2. But the rate of increase in photosynthesis with rising CO_2 will eventually diminish and approach an asymptote as CO_2 levels reach double that of the present day[2,3].

How other factors affecting leaf photosynthesis and its conversion of carbohydrates into plant matter respond to elevated CO_2 depends on a variety of conditions: for example, whether plants are growing in isolation or in groups[4]; are woody or herbaceous[4,5]; are growing as monocultures or as mixed