of γ-H2A.X. This is plausible, as the WICH complex also has chromatin-remodelling activity during DNA replication[7,8].

The main conceptual issue arising from Cook and colleagues' results[6] is the proposed role of phosphorylated Y142 in promoting cell death. On one hand, the authors provide evidence for increased H2A.X–JNK1 interaction in cells exposed to high doses of radiation. This indeed supports the switch model, as such Y142-mediated recruitment of JNK to sites of DSBs helps direct cells towards apoptosis as a last resort. On the other hand, they show that Y142 is dephosphorylated after DNA damage, resulting in the loss of the 'docking site' for JNK1. At first glance at least, this finding does not fit the switch model, calling for more work to reconcile it with the observed pro-apoptotic effects of Y142 phosphorylation. It may be, however, that Y142 is re-phosphorylated after futile attempts to repair excessive DNA damage.

Clearly, the issue of the efficiency of DSB repair and the role of posttranslational chromatin modifications in this process is here to stay. Nevertheless, the two papers[5,6] provide a fresh conceptual framework and tools to tackle this challenge, which should enable us to better understand the genesis of major genome-instability diseases, including cancer, premature ageing and neurodegeneration. ■

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ENVIRONMENTAL SCIENCE

Clean coal and sparkling water

Werner Aeschbach-Hertig

Subsurface storage of carbon dioxide is a major option for mitigating climate change. On one account, much of the gas sequestered in this way would end up as carbonic acid in the pore waters of the host rock.

Atmospheric concentrations of greenhouse gases, especially carbon dioxide, continue to rise at an alarming rate. We seem unable to tame our appetite for fossil fuels on a meaningful timescale, and the concept of carbon capture and storage has emerged as a serious option for reducing CO_2 emissions to the atmosphere. A 'clean coal' technology, in which CO_2 is collected from coal-fired power plants and stored safely below ground, might enable us to continue using this comparatively cheap and abundant energy source without climatic worries.

However, little is known about the long-term fate of large quantities of CO_2 put into geological storage. Gilfillan *et al.*[1] (page 614 of this issue) illuminate this crucial matter by showing that dissolution in groundwater is by far the most important trapping mechanism for CO_2 in the subsurface environment. In other words, sequestering CO_2 in geological formations would probably produce vast quantities of highly CO_2-enriched sparkling water.

The safety of geological storage of CO_2 is obviously a central concern in planning carbon sequestration on a large scale. When CO_2 is injected into the subsurface, it will be retained by physical and geochemical mechanisms[2]. Physical trapping is provided by the presence of sealing, low-permeability rock formations above the targeted layer. Such cap rocks are essential features of natural gas and oil reservoirs, and are a primary requirement for CO_2 storage sites. A further level of safety is added by geochemical interactions that remove the pure CO_2 phase, either through dissolution in water (solubility trapping) or by precipitation of carbonate minerals (mineral trapping). Clearly, mineral trapping is the preferable pathway, as it promises to store the carbon over geological timescales.

To assess the risk of leakage from storage reservoirs, an expansive programme for monitoring underground CO_2 injection in a variety of geological settings has been called for[3]. There are only a few currently active pilot sites, and more are needed. But that apart, such monitoring programmes can reveal the effects of carbon sequestration only on the engineering timescale — they do not yield a direct answer to questions regarding the long-term behaviour of CO_2 in geological storage.

In this respect, the approach taken by Gilfillan *et al.*[1] is logical and informative. The authors used CO_2-rich gas fields as natural analogues for future carbon-storage sites. Other researchers have exploited this idea[4]. But in offering a self-consistent evaluation of noble

NATURE

50 & 100 YEARS AGO

50 YEARS AGO

It often happens that investigators, particularly in the social sciences, must try to collect the information which they need by using questionnaires. One of the many problems that are apt to arise concerns the reliability of answers to questions which require an exercise of detailed and specific memory. Recently, the Tobacco Manufacturers Standing Committee issued a Research Paper (No. 2) entitled "The Reliability of Statements about Smoking Habits" by G. F. Todd and J. T. Laws ... The authors show how statements about current smoking habits are generally reconstructed from a sort of 'mental picture' that the informant has of himself 'in his role as a smoker'. Changes in smoking habits are far more frequent than is generally thought to be the case, and so any information about them which refers to the past, based, as it must be, upon a general and personal assessment of current practices, is very likely to be in error ... recall is frequently mistaken both as regards the amount and the kind of smoking carried on. Apart from the special topical interest of this study, it has wide methodological implications which ought to be considered by all users of questionnaires.

From *Nature* 4 April 1959.

100 YEARS AGO

The influence of breed on egg-production in poultry is well seen in a report recently issued by Messrs. E. and W. Brown from University College, Reading. Danish, American, and English Leghorns were kept under comparable conditions for twelve months, and careful record was kept of the number of eggs laid. The Danish birds had been bred to yield a large number of eggs of moderate size; the English birds, on the other hand, had been largely bred for exhibition purposes, for which egg-producing capacity is not needed ... The profit on the English birds is shown to be much less than that on the Danish or American birds.

From *Nature* 1 April 1909.

W. AESCHBACH-HERTIG

Figure 1 | Bubbling up. The Wallender Born or 'Brubbel', a CO_2-driven cold-water geyser in the village of Wallenborn in western Germany, provides a natural illustration of CO_2 leakage from geological storage. Although largely harmless, such leakage would be undesirable in carbon-sequestration projects.

gas and carbon isotope data from nine natural gas fields in the United States, China and Hungary, the present study stands out by virtue of the large range of gas fields included and the methods used to identify the fate of the CO_2.

A central parameter of this analysis is the $CO_2/^3He$ ratio of the gases. The basic idea is that ^3He, a noble-gas isotope originating almost exclusively from Earth's mantle, behaves as a conservative tracer in the crustal environment of the gas reservoirs studied. The primary gas emplaced in these reservoirs has a characteristic $CO_2/^3He$ ratio, often indicating that it is of magmatic origin. Any reduction of this ratio is ascribed to the removal of CO_2 from the gas phase.

Gilfillan and colleagues' first, intriguing, finding is that declining $CO_2/^3He$ ratios in the gases are related to increasing concentrations of ^4He and ^{20}Ne. These correlations hold within individual fields as well as across the combined data set. The authors argue that this systematic behaviour strongly suggests that the gas has interacted with water, which provides a plausible source of crustal ^4He and atmospheric ^{20}Ne. Whereas the highly soluble CO_2 dissolves in the groundwater, the low-solubility noble gases He and Ne degas from the water into the gas phase, thereby producing the observed relationships. This indicates that solubility trapping is an important process, but does not rule out the possibility that mineral trapping also occurs.

A quantitative assessment of the contributions of the two trapping mechanisms is provided by a second line of evidence based on the $^{13}C/^{12}C$ isotope ratios of the CO_2 gas. This ratio is expected to change if CO_2 is removed by the formation of carbonate minerals, as the heavier isotope ^{13}C precipitates preferentially. Such an isotope fractionation also occurs as CO_2 dissolves in water, but to a lesser degree, depending on the prevailing pH conditions. By comparing the observed relationships between the $CO_2/^3He$ ratio (as a measure of CO_2 removal) and the $^{13}C/^{12}C$ isotope ratio in the different gas fields with models of the expected fractionation for either process, the authors show that the data are incompatible with mineral trapping, but can be explained by dissolution in water.

Gilfillan and colleagues' overall conclusion[1] is that in the nine gas fields investigated, covering different geological settings, solubility trapping played a major part, removing up to 90% or more of the initially emplaced CO_2. Mineral trapping played a minor part at best. Although dissolution in groundwater implies the possibility of CO_2 transport and eventual leakage to the atmosphere, as illustrated by Figure 1 and as is thought to occur in natural gas fields[4], this result does not mean that safe geological storage is impossible. But it highlights the need for a thorough assessment of the hydrogeological setting of prospective storage sites. And it demonstrates the power of the methods involved in assessing the effectiveness of different geochemical trapping mechanisms. ■

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HIV

Immune memory downloaded

Dennis R. Burton and Pascal Poignard

An impressive system for retrieving large numbers of antibodies from memory B cells has been developed. It has been put into practice in an investigation of immune responses to the human immunodeficiency virus.

Infection of an individual with a virus or a bacterium triggers a vigorous response in white blood cells, some of which — B cells — are stimulated to produce antibodies that target the invading pathogen. The antibodies may be produced too late to prevent symptoms of infection, but the next contact with the same pathogen will probably be symptom-free as antibodies are rapidly deployed to clear the pathogen.

This antibody 'memory', which is crucial to vaccine efficacy, has two forms: antibodies circulating in the blood, made by a very-long-lived type of B cell in the bone marrow known as a plasma cell; and B cells in the blood that can be stimulated to make antibodies on contact with a pathogen[1,2]. The latter 'B-cell memory' carries a record of the antibodies an individual has made in response to a given pathogen, and is of great interest, not least in guiding the design of better vaccines. On page 636 of this issue, Scheid *et al.*[3] describe the detailed characterization of B-cell memory responses in the context of infection with the human immunodeficiency virus. The paper contains insights that are both of a general nature and likely to be specific to HIV.

Dissection of the B-cell memory response in human blood requires individual monoclonal antibodies (specific for particular sites on pathogen molecules) to be isolated from each B cell or each set (clone) of identical B cells. Scheid *et al.* accomplished this tour de force by selecting single-memory B cells specific for a preparation of the surface glycoproteins of HIV, amplifying antibody genes from each cell and then producing each antibody in a cell line (Fig. 1). In principle, sufficient numbers of B cells were sampled to reflect the full response to the glycoproteins. These glycoproteins were chosen because they are the sole target of antibodies able to neutralize the virus and prevent infection. The authors studied six HIV-infected donors whose blood sera can neutralize, to varying degrees, a range of different isolates of HIV. By analysing the antibody responses of the donors in detail, it was hoped to understand the origins of this broad neutralization.

Scheid and colleagues did most of their work on four donors, on average isolating more than 100 monoclonal antibodies to the surface glycoprotein preparation per donor. Each antibody was exhaustively characterized at the genetic and protein levels. The antibodies from each donor could be classified into 20–50 families of antibody, with varying numbers of close relatives in each family. The sequences of the antibodies in each family are highly divergent from the sequences characteristically found