might increase the efficiency of this pump — thereby drawing more CO_2 out of the atmosphere — by artificially supplying nutrients to the surface oceans. This suggestion is highly contentious. Papers by Boyd *et al.*[1], Abraham *et al.*[2] and Watson *et al.*[3] (pages 695, 727 and 730 of this issue) will add fuel to the debate about the desirability of such 'geoengineering' solutions to Earth's ills. The papers describe the results of a fertilization experiment in the Southern Ocean, around Antarctica, and its scientific implications for interpreting past climate change.

Phytoplankton biomass in the global oceans can usually be correlated with the supply of nitrogen, phosphorus and silicon upwelling from the deep sea to the sunlit surface waters where photosynthesis takes place. In the equatorial Pacific and the Southern Ocean, however, these supplies far exceed demand, indicating that some other factor is limiting phytoplankton growth. This mystery plagued oceanographers for decades until the late John Martin showed that the limiting factor is iron, a trace element that reaches the oceans in atmospheric dust[4]. Analyses of ancient ice cores show that dust deposition varied significantly during glacial and interglacial periods, and is anticorrelated with concentrations of atmospheric CO_2 over the past 400,000 years. So Martin reasoned that airborne iron supply could in part regulate climate by increasing the efficiency of the biological pump. He further suggested that very small amounts of iron distributed in today's Southern Ocean could draw a significant amount of CO_2 from the atmosphere. This is partly because the Southern Ocean is huge and, apart from iron, holds vast quantities of unused nutrients, and partly because its surface waters tend to sink, delivering carbon to the deep ocean.

With this as a backdrop, Boyd *et al.*[1] launched the SOIREE expedition (for Southern Ocean iron release experiment) in February 1999. They distributed 8,663 kg of an iron compound over a patch of ocean 8 km in diameter, some 2,000 km south-south-west of Hobart, Tasmania. The experiment was a dramatic success. Physiological indicators of iron stress decreased in the

Box 1 Commons concern

Whole-ecosystem experiments have revolutionized ecology[9]. With three successful ocean-fertilization experiments[1,5,10], oceanographers have joined that revolution. The discovery that iron limits phytoplankton growth in the equatorial Pacific and Southern Ocean has made it possible to stimulate the productivity of hundreds of square kilometres of ocean with a few barrels of fertilizer. By contrast, it would take roughly 3,000 times as much nitrogen and phosphorus to fertilize the North Atlantic, where these elements are limiting.

This is a powerful new tool for oceanographers, because by transient perturbation of the ecosystem from its quasi-equilibrium state we can glimpse the mechanisms that keep it there. These mechanisms, which consist of tightly coupled production and consumption processes in a complex food web (Fig. 1), hold one of the keys to understanding the connection between the oceans and the climate.

With powerful tools comes the responsibility of deciding how to use them. Small-scale scientific experiments are one thing. But the correlations between iron availability, marine productivity and climate change have led to the prospect of using ocean fertilization to manipulate climate.

Coupled with the post-Kyoto possibility of a global market in carbon emissions trading, including the issuing of 'carbon credits'[11], this idea has spawned a budding industry[12,13]. Patents on ocean fertilization have been issued to entrepreneurs and large corporations[14], and there are plans for a 8,000-km^2 'demonstration experiment'[15]. With a few exceptions[16], little attention is being paid to the risks of large-scale fertilization. But we will be forced to make decisions about this technology, and quickly, whether we are ready or not.

In deciding on future uses of the ocean Commons, we have an opportunity to learn from past mistakes. The oceans are a complex adaptive system, so it is impossible to predict the long-term consequences of commercial ocean fertilization. How then can we decide whether to proceed? We need to "reach for lessons"[17].

The Earth system consists of elements distributed between the land, air and oceans by biological and geological processes over millions of years. Many environmental problems stem from our moving elements between these compartments at unprecedented rates that the system cannot accommodate. Importing massive quantities of nitrogen from the atmosphere to the land through fertilizer production, for example, has increased the production of the greenhouse gas nitrous oxide, and destroyed the ecology of coastal waters. Burning fossil fuels has moved massive amounts of carbon from the land to the atmosphere, and threatens to warm the globe. The direct and large-scale fertilization of the sea would undoubtedly have similar unintended consequences. The lesson is simple. In the long run, ocean fertilization is not sustainable. So why start? **S.W.C.**

100 YEARS AGO

The New York correspondent of the *Lancet* states that the Chicago Board of Education has established a department called "Child-study and Pedagogic Investigation". The examination is undertaken for the purpose of determining the mental and physical status of the school-children. Examinations were at first limited to the determination in each pupil of the following points: Height, height sitting, weight, ergograph work, strength of grip right and left, hearing right and left, and acuity of vision. In addition to this, obvious developmental defects have been noted. The number of children examined down to the present time is 5636. The conclusions thus far reached are that there is a physical basis of precocity, that dull children are lighter and precocious children heavier than the average child, and that mediocrity of mind is associated with mediocrity of physique… This is the first instance of a municipal board in America appropriating money for research work, and its effect may be far-reaching.

From *Nature* 11 October 1900.

50 YEARS AGO

There has probably never been a time in the history of the oil industry when 'petrol', to use the colloquial term, has engaged so forcibly public attention in Great Britain and elsewhere. Once rationing is imposed on any commodity which has been taken for granted, as up to 1939 petrol certainly was and likewise food (water has always been), there is solid basis for the ordinarily complacent citizen to know the reason why and to bestir himself to the facts. Even to keep a ration going for vital needs in time of emergency and stress is a formidable task; had it not been for amazing advances in technique of producing motor fuels by processes developed during the Second World War and afterwards, one wonders whether, indeed, economic factors aside, the petrol ration would not be with us in Britain and in Europe generally for years to come. The explanation of these advances is, of course, highly technical; it rests on the extraordinary rate of evolution in refinery procedure during the past decade and on conversion of petroleum in the more or less raw state into motor fuels by specialized thermal and catalytic processes. Dr. A. N. Sachanen devotes his large book to this complex subject and to the technologist.

From *Nature* 14 October 1950.

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