the remaining NO_3^- in the heavy isotope (^{15}N). When this water is brought to the surface and the nutrients it contains are used in photosynthesis, the phytoplankton become enriched in the heavy isotope. This signal is then transferred to and preserved in sediments when the phytoplankton remains decompose. In both areas there are strong correlations between nitrogen-isotope ratio and estimates of the temperature record, with enriched values during warm periods and depleted values during cold periods.

The record presented by Altabet *et al.*[5] extends back 65,000 years into the most recent ice ages. It is exceptionally detailed and the pattern it shows is strikingly similar to that of Dansgaard–Oeschger (D–O) events observed in Greenland ice cores[6]. These D–O events are warm periods that punctuated the ice ages roughly once every 3,000 years. Altabet *et al.* assume that the isotopic signals and D–O events are synchronous, and interpret the record as showing that, in a matter of centuries, conditions in the Arabian Sea have switched from there being little or no denitrification during cold periods to denitrification as intense as that which occurs today in warm periods. According to the alternative hypothesis, however, increased nitrogen fixation during the most recent glaciation would also have increased the marine nitrogen inventory and altered the isotopic balance, as observed, because nitrogen fixation adds fixed nitrogen depleted in the light isotope relative to the oceanic pool.

One thing that has perplexed palaeoceanographers is the asynchrony of climate change in the Antarctic and in Greenland[7]. Greenland temperature records during the most recent ice ages show 24 D–O warm periods, which are characterized by rapid warming and subsequent slow cooling[6]. Antarctic temperature variations show fewer, less pronounced warmings, and are rather gradual[7]. Altabet *et al.* suggest a possible mechanism for this. If the changes in denitrification inferred from their Arabian Sea cores indeed affected the nitrate inventory of the oceans (and, in turn, the CO_2 content of the atmosphere), then the timescale of the inventory change would be damped by the residence time of nitrate in the ocean, which is currently estimated at about 3,000 years[3,8].

Smoothing their isotope record with a 3,000-year moving average, Altabet *et al.* have produced an isotope time series which, they argue, should reflect the marine nitrate inventory as being affected by denitrification in the waters of the Arabian Sea (which accounts for about one-third of the water-column denitrification in today's ocean). Between 65,000 and 25,000 years ago, this record is strikingly similar to Antarctic ice-core temperature and CO_2 records, implying that denitrification-driven variation in the nitrogen cycle contributed to changing atmospheric CO_2 levels during this period.

One caveat, which is acknowledged by Altabet *et al.*, is that plankton must have been able to use this greater resource of fixed nitrogen during the most recent glaciation without a commensurate change in the phosphorus inventory — that is, the Redfield ratio was not fixed at 16:1. The hypothesis put forward by Altabet *et al.* is appealing. But because they have assumed that changes in denitrification were synchronous with D–O cycles, we cannot yet establish the timing of the changes in the nitrogen inventory, and thus determine whether they preceded or followed changes in atmospheric CO_2 and temperature. In other words, it cannot be said which was the cause of the other.

So has the glacial–interglacial increase in atmospheric CO_2 levels ultimately been driven by changes in the nitrogen cycle? It may depend on how rigidly Mother Nature enforces the Redfield ratio. If it is strictly enforced, as Ganeshram *et al.*[4] suggest, then any increase in nitrate concentration in the oceans caused by reduced denitrification, or increased nitrogen fixation for that matter, would not affect marine photosynthesis without a commensurate change in phosphorus concentration. If, on the other hand, enforcement of the ratio is somewhat lax, then changes in the fixed nitrogen inventory, no matter how they are driven, and the consequential changes in marine carbon fixation, might well explain fluctuations in atmospheric CO_2 levels.

The place to look for the answers may again be the marine sedimentary record. The oceans are currently about 5‰ enriched in ^{15}N relative to atmospheric N_2. Denitrification removes nitrate with an isotopic composition that is about 20‰ depleted in ^{15}N, whereas nitrogen fixation adds fixed nitrogen with a composition that is almost identical to that of atmospheric N_2. So changes in the nitrate inventory that are driven by changes in either process should modify the ocean-wide isotopic composition of fixed nitrate and show up in certain places in the sedimentary record. Coaxing information on changes in the N:P ratio from this record, however, will be a more difficult challenge. ■

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Daedalus

Hold on to your heat

Human skin loses a lot of heat. Clothes and fire are some of the most important inventions in our history, but they are still far from perfect. The 'goose-flesh' effect, in which a sudden frightening or frigid circumstance erects the local muscles and makes our skin hair stand on end, traps some insulating air but is feeble compared to the same process in cats, for example. We have to add or remove clothes several times a day, and often have difficulty getting to sleep because bedclothes have fixed heat loss.

So Daedalus is inventing a fabric with a variable insulation capacity. It has a current-carrying wire threading it, and magnetic fibrils wrapped around the wire. When a current flows, all the fibrils become magnetic the same way. They all repel each other, and stand up at right-angles to the wire. When the current ceases, they lie down again.

To minimize problems of power drain, the first product will be an eiderdown for a bed, accessible to the main power supply. Sleeping, that primitive need, often conflicts with the civilized need to stay up late. Furthermore, inflexible inventions such as the futon have made it harder to go to sleep. So our animal needs invite technical help. The DREADCO team's eiderdown has insulation that varies in different places and at different times. When the program is perfected, its user will get to sleep rapidly and stay asleep for longer. The resulting programmed bed might even be arranged to wake the sleeper up suddenly, by cooling at the right time. There may be no need for an alarm clock.

Working on the bed design will tell the team which fabric works best, what minimum current will increase insulation by a given factor, and so on. They will then be able to design simple dresses or trousers carrying their own rechargeable batteries. These should allow a wearer to move between rooms held at differing temperatures, or even to pop outside to the shops for a moment, without having to struggle into a coat.

But variable heat-loss garments pose a serious problem for all fashion designers. Underclothes are perhaps the easiest challenge; they allow considerable freedom for providing insulation. But the fashionable young must create the impression that they have endless body heat to spare. The design and placing of insulation panels in fashionable garments for the young will tax even DREADCO's designers to the limit.

David Jones

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