

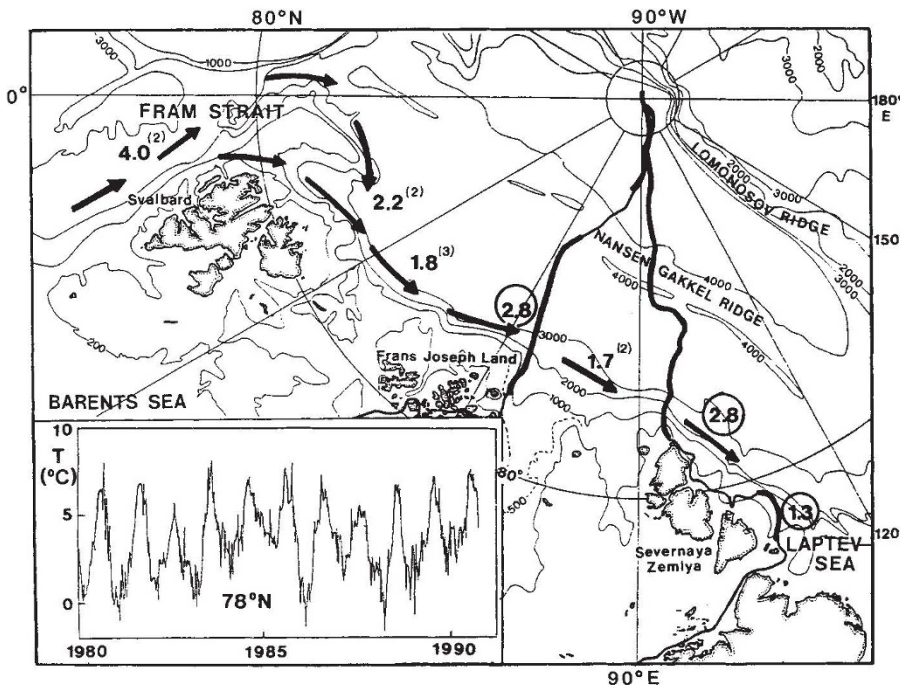
Warming in the Arctic

SIR — Climate models predict that global warming caused by the greenhouse effect will not be distributed evenly¹. The greatest temperature increase is expected for the polar and subpolar regions, with a relatively small change in the tropics. The polar regions may therefore be well suited to attempts to observe climate changes, but severe environmental conditions make it difficult to obtain such data, particularly in the case of the Arctic Ocean, which has a permanent ice cover and is thus virtually inaccessible to normal ocean-going vessels.

through turbulent mixing and diffusive fluxes.

Climatological² and synoptic data collected in 1987 (ref. 3) show that the maximum temperature in the Atlantic water decreased from about 4 °C in the ice-free Fram Strait to below 2 °C in the subsurface layer between Svalbard and Severnaya Zemlya. But our temperature measurements made in 1990 off Frans Joseph Land and north of Severnaya Zemlya had maxima of 2.8 °C, about a degree higher.

The ice thickness encountered during the



Maximum temperature in the Atlantic layer over the Eurasian Basin of the Arctic Ocean. Circled numbers, *Rossiya* observations along the tracks shown as bold lines. Other numbers are taken from the references given in brackets. The inset shows the maximum sea surface temperature in Fram Strait at 78° N during 1980–90.

During August 1990, the Soviet ice-breaker *Rossiya* carried a group of tourists from Murmansk to the North Pole, cutting across the Eurasian basin at longitudes 60° E and 95° E. Detailed observations of the ice were made as well as closely spaced temperature profile measurements in the upper 500 m of the water column, using expendable bathythermographs dropped in leads or small polynyas.

The Arctic Ocean water column consists principally of three layers: a cold and low salinity surface layer; a warm and salty Atlantic layer in the depth range 100–800 m; and the deep water below, being cooler and slightly fresher. The Atlantic layer derives from an inflow in the Fram Strait between Svalbard and Greenland and is the northernmost extension of the Gulf Stream–Atlantic current system. On its way north it loses heat to the atmosphere, and in or just north of Fram Strait subducts underneath the ice and polar water, continuing to lose its heat

cruise was 20–30% smaller than the climatological mean for the area⁴, although this might simply reflect that the vessel was taking the route of least resistance, avoiding thick old massives and other heavy ice features. It is of course not immediately clear whether the higher subsurface temperatures and the lower ice thickness already reflect a climate trend or just some normal interannual variability. The sparseness of the available data simply does not allow any such conclusion. Sea-surface temperature variability in Fram Strait is high, both on seasonal and interannual timescales. The year-to-year changes of 2 °C could mask any trends in temperature development. It seems clear, however, that there is a need for careful

1. Mikolejczewicz, U., Santer, B. D. & Maier-Reimer, E. *Nature* **345**, 589–593 (1990).
2. Gorshkov, S. G. *Atlas of the Oceans: The Arctic Ocean* (Pergamon, New York, 1983).
3. Anderson, L. G. *et al.* *Deep Sea Res.* **36**, 475–482 (1989).
4. Bourke, R. H. & Garret, R. P. *Cold Reg. Sci. Tech.* **13**, 259–280 (1987).

monitoring of the heat fluctuations in the Arctic, a region so vulnerable to changes in global climate.

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Clonal defence

SIR — Dye *et al.*¹ have criticized our clonal theory of parasitic protozoa² by pointing out that “clonality is the conventional wisdom” and that “sexual reproduction clearly occurs, [although . . .] may not be common in nature”. Unfortunately, they fail to understand the significance of our theory.

We are not denying that sexual reproduction may occur nor simply asserting that clonality may be a common mode of reproduction for parasitic protozoa, both of which are indeed well known. Our hypothesis is that parasitic protozoa have a clonal population structure, which in turn implies that sexual reproduction is very rare even on the evolutionary scale. The theory has momentous evolutionary as well as medical consequences. In *Trypanosoma cruzi*, for example, where the evidence supporting the hypothesis is overwhelming, the average genetic differentiation between two randomly sampled clones is greater than that between gorillas and humans. Generally, if the population structure is clonal it is not warranted to assume that any clone or a few of them may be representative of the species with respect to biological and pathological properties.

Walliker *et al.*³ argue that our theory is likely to be wrong with respect to the agent of human malaria *Plasmodium falciparum*. This may be so, but none of their four points will settle the issue. Because of the well-known fact that a sexual stage is required in the mosquito vector to complete the infection cycle, we were surprised that our analysis² of the limited data available supported a clonal population structure. In addition to a clonal population structure for the whole taxon, it is also possible that both biparental and uniparental lineages may coexist in nature — a phenomenon known to occur in many metazoa and plants.

The issue of the population structure of *P. falciparum*, as in the other protozoa, can be settled only by population-genetic evidence concerning the distribution of genotypes in natural populations. We reported the analysis supporting clonality as a challenge to those who work on *P. falciparum* to settle the