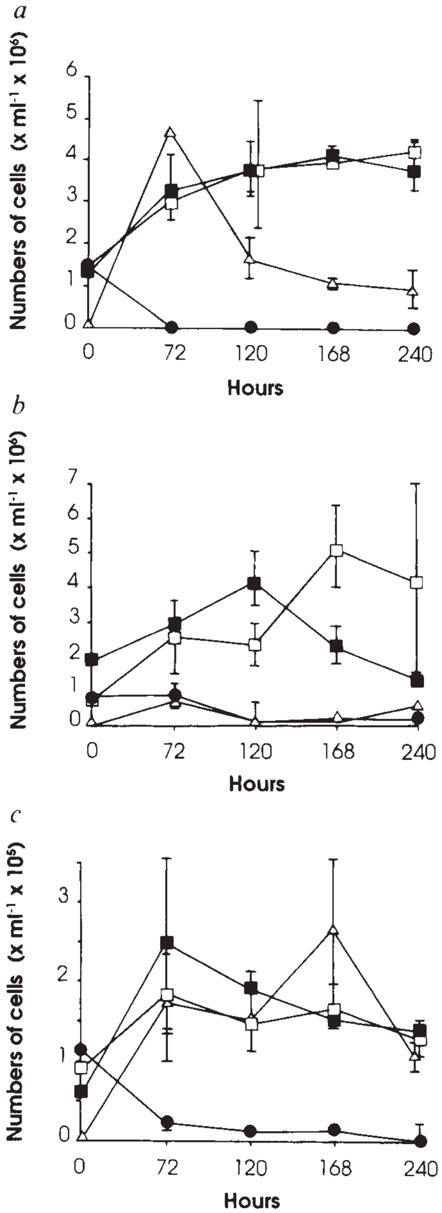
Diatom kills by flagellates

SIR — The idea of 'distinct trophic levels' (see ref. 1), with producers, consumers and predictable food chains, has been challenged[2,3]. Here we show that the common bacterivore flagellate *Cafeteria roenbergensis* caused mass mortality in cultures of various marine diatoms, thereby supporting increased growth of bacteria feeding on the decaying algae. When inoculated with diatoms, algae flocculated into larger aggregates crowded with flagellates within a few days, causing the sinking and senescence of the cultures. This 'gardening' mechanism may be important in promoting sudden collapses of diatom blooms, formation of marine 'snow' and sequestration of carbon from a grazer food chain to a detritus food chain.

We investigated this phenomenon after repeatedly observing flocculation and subsequent dieback of *Skeletonema costatum* in cultures contaminated with the flagellate *C. roenbergensis.* We added *C. roenbergensis* to the common marine diatoms *S. costatum, Chaetoceros socialisis, Thalassiosira pseudonana* and the cryptomonad *Rhodomonas baltica.* At 24-hour intervals for 7 days, we counted numbers of bacteria, *C. roenbergensis* (identified by N. Vørs) and algae by using both Utermöhl counting chambers and a combined DAPI and Primulin staining method[4]. We observed that *C. roenbergensis* attached to the surface of *C. costatum* after 24 hours and that after 48 hours, aggregates apparently generated by the flagellates were beginning to evolve. When the aggregates began to decay, they were heavily colonized by bacteria which, again, were grazed by *C. roenbergensis.* Complete algal dieback was observed during the following 5 days. The same pattern was observed for the other species of diatoms investigated, but no effect was observed for the cryptomonad.

To test whether extra cellular cellulytic enzymes were involved in the formation of aggregates, we inoculated algae with filtrate from cultures with decaying algae and a dense population of the flagellate (collapsed culture). Fresh 10-ml batch cultures of diatoms were added to 1 litre of 0.2 μm filtrate (removing flagellates) from the collapsed cultures and followed for 10 days. This procedure also served as a test for pathogenic viruses which could cause corresponding collapses in algal populations[5], as viruses would have been present in the filtrate. In parallel, we inoculated fresh cultures of algae with *C. roenbergensis.* Fresh cultures of algae without added filtrate or flagellates served as controls. Each culture was counted at 24-hour intervals, and we observed the same effect. Aggregates of sinking algae were formed soon after addition of *C. roenbergensis*, while there were no such effects in the algae exposed to filtrate where *C. roenbergensis* had previously been present.



a, S. costatum; b, T. pseudonana; c, C. socialis. Results from the growth experiment. Filled boxes, numbers of cells in the control cultures; open boxes, number of algal cells in culture added to 0.2 μm filtrate from collapsed culture; filled circles, number of algae in cultures added. *C. roenbergensis*; triangles, number of *C. roenbergensis* in the cultures denoted by filled circles.

Diatoms are dominant among marine phytoplankton in most northern waters, forming frequent spring blooms which can suddenly collapse. Such blooms are recognized sources of marine 'snow'. Because grazing losses are low, significant amounts of carbon from sinking blooms are sequestered to the sediments[6]. Protists, mainly small heterotrophic flagellates, have been described as the pioneer organisms that colonize marine snow[7], and *C. roenbergensis* is a common heterotroph nanoflagellate reported to be a common marine snow protist throughout the world[8].

We suggest that marine protists not only colonize marine snow but play an active part in the formation of such aggregates. This may be an important mechanism promoting termination of diatom blooms. The phenomenon of flagellates controlling organic aggregates has been observed in sewage plants, which rely on microbial flocculation involving protists. The same phenomenon may be at work here, suggesting that flagellates have a significant impact on primary production, energy budgets and carbon flux by 'triggering' a sink from energy generated by photosynthesis in the euphotic zone.

Kari Nygaard
Dag O. Hessen
NIVA, PO Box 173 Kjelsås, N-0411 Oslo, Norway

1. Lindeman, R. I. *Ecology* **23**, 399–418 (1942).
2. Bird, D. F. & Kaiiff, J. V. *Science* **231**, 493–494 (1986).
3. Polis, G. *Am. Nat.* **138**, 123–155 (1992).
4. Nygaard, K. N., Børsheim, K. Y. & Thingstad, T. F. *Mar. Ecol. Prog. Ser.* **44**, 159–165 (1988).
5. Suttle, C. A. *et al. Nature* **347**, 467–469 (1990).
6. Wassmann, P. *Mar. Poll. Bull.* **21**, 183–187 (1990).
7. Caron, D. A. in *The Biology of Free-living Flagellates* (Eds Patterson, D. J. & Larsen, J.) 77–92 (Oxford University Press, Oxford, 1991).
8. Patterson, D. J. *et al. J. Mar. Biol. Ass.* **73**, 67–95 (1993).

Sex and longevity

SIR — Nieschlag *et al.*[1] say that "...the difference in life expectancy between men and women may be related to another factor, probably Y-chromosome-mediated, rather than to testosterone and the testes." We agree that testosterone and the testes are not related to sex differences in life expectancy simply because boys die more often at any age[2]. We also agree that it is reasonable to assume that gender gap in human longevity is "probably Y-chromosome mediated" simply because male sex itself is linked to the Y-chromosome in humans.

There is, however, one important observation which should be taken into account: in other mammalian species (such as rats, mice and hamsters) where male sex is also linked to Y-chromosome, males generally do not live shorter than females[2]. Thus, Y-chromosome *per se* cannot be a general explanation for sex differences in life span.

Leonid A. Gavrilov
Natalia S. Gavrilova
A. N. Belozersky Institute, Moscow State University, Moscow 119899, Russia

1. Nieschlag, E., Nieschlag, S. & Behre, H. M. *Nature* **366**, 215 (1993).
2. Gavrilov, L. A. & Gavrilova, N. S. *The Biology of Life Span: A Quantitative Approach* (Harwood Academic, Chur, London, 1991).