lowest dose that has been tested and found to be carcinogenic in rodents. Such an exposure is greater than the known DMN exposures from nitrite preserved foodstuffs (*18*). The public health effects of exposure to such concentrations of carcinogens remain to be assessed. Of possible interest in this connection are recent epidemiological findings (*19*) which, despite their possible limitations, suggest an association between ambient community NO_x levels and cancer.

Note added in proof: The experiments reported here have since been repeated by several independent workers (*20, 21*), including scientists from the chemical companies involved (*22, 23*). They have all confirmed the presence of DMN by GLC–mass spectrometry techniques. In Baltimore, the source was found to be the chemical plant which was using DMN as an intermediate; the plant was ordered closed as of April 1976 (*21*). In Belle, the DMN was traced to the amine manufacturing facility. This company has now reported that they have found a point-source discharge of DMN (*23*).

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12. The TEA-GLC furnace temperature was 300°C; cold trap temperature, −150°C; chamber pressure, 3.6 mm-Hg; and nitrogen carrier gas, 30 ml/min. The GLC column was stainless steel, 21 feet by ⅛ inch (outer diameter), with the first 8 feet packed with 2 percent KOH and 5 percent free fatty acid phase (FFAP) on Chromosorb WHP 80/100 mesh and the remainder packed with 10 percent FFAP on Chromosorb WHP 80/100 mesh. The GLC temperature was 185°C. A Thermo Electron TEA model 502 was used.
13. The TEA-HPLC furnace temperature was 400°C; cold trap temperature, −150°C; chamber pressure, 3.5 mm-Hg; and HPLC flow rate, 2.0 ml/min.
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16. Using TEA-HPLC and an analytical technique similar to that described here, D. H. Fine (unpublished data) detected several *N*-nitroso compounds in the exhaust gases from a truck diesel engine and an automobile internal combustion engine. The identity of the compounds has not yet been established.
17. An average person takes 16 breaths per minute, with a volume of 0.45 liter each. In the course of a 24-hour day, a person inhales 10,400 liters of air weighing 14,000 g. If the air had a DMN content of 1 ppb, the daily DMN intake would be 14 μg, or 0.35 μg/kg for a 40-kg person. This is to be compared with 50 μg/kg, which has been shown to be carcinogenic in rodents (*4*).
18. Cooked bacon, bologna, and smoked ham have a DMN concentration of approximately 1 to 5 μg/kg. If 100 g of these foods were eaten daily, the daily intake of DMN could only be as high as 0.5 μg.
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Size Variations in Planktonic Foraminifera: Implications for Quantitative Paleoclimatic Analysis

Abstract. *Populations of planktonic foraminiferal species and phenotypes, distinguished on the basis of color and coiling direction, reach maximum average test sizes in their regions of optimum development. Therefore, tropical species are largest in tropical waters, while polar species are largest in polar waters. Species living in subtropical and subpolar waters decrease in test size with both increasing and decreasing temperature.*

Previous studies of test size variations in planktonic foraminifera indicate that (i) size variations form mappable geographic patterns and (ii) tropical species are larger in test size in warmer waters and decrease in size with decreasing temperature, while polar species are larger in test size in polar waters and decrease in size with increasing temperature (*1–3*). These observations suggest an ecologic model in which foraminiferal species reach maximum average test size in their optimum water masses, and decrease in size away from such areas (*4*). This im-

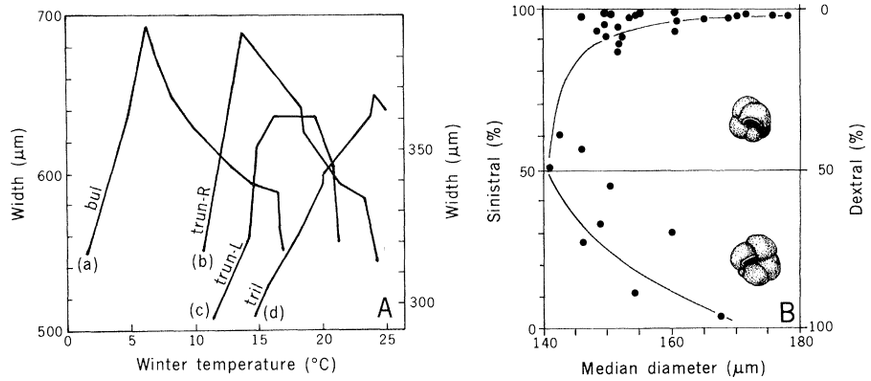

Fig. 1. (A) Variations in maximum average test size (*5, 6*) as a function of winter temperature in the North Atlantic for populations of (a) *G. bulloides* (bul), (b) *G. truncatulinoides* right (trun-R), (c) *G. truncatulinoides* left (trun-L), and (d) *G. trilobus* (tril). The scale on the left is for populations of *G. truncatulinoides*; that on the right is for *G. bulloides* and *G. trilobus*. (B) Correlation of abundances and median test sizes in right- and left-coiling populations of *G. pachyderma*. [Data are from Kennett (*2*)]

plies that for subtropical or subpolar species, size should decrease with both increasing and decreasing temperatures.

Figure 1A shows that populations of the subpolar species *Globigerina bulloides* are larger in test size in the north-central Atlantic south of the polar front, at 60°N latitude, between winter temperatures of 5° and 10°C, and decrease in size to the north and south (*5, 6*). By contrast, the tropical species *Globigerinoides trilobus* is largest in tropical waters, at winter temperatures greater than 20°C, and decreases in size with decreasing temperature. Similar data have been obtained for a second tropical species, *Globigerinoides ruber*, and for *Orbulina universa*, which shows a clear pattern of increasing test size with temperature (*7*). For the subtropical species *Globorotalia truncatulinoides*, right- and left-coiling populations are both largest in subtropical waters (albeit at different temperatures and salinities) and decrease in size with increasing and decreasing temperatures. It is important to note that right-coiling populations of *G. truncatulinoides* are larger in test size than are left-coiling ones. Finally, Fig. 1B shows size variations in the polar species *Globigerina pachyderma*. This species is also separated on the basis of right and left coiling directions, since left-coiling forms increase in abundance with decreasing temperature and are the only species present in polar waters. Right-coiling forms are dominant in subpolar waters and decrease in abundance with increasing and decreasing temperatures. Figure 1B shows a close correlation between size variations and abundance changes for this species (*8*). These data suggest that there is an optimum region for development of maximum size and that this region corresponds to the preferred water mass for each species.

The hypothesis outlined above is contradicted by Bé *et al.* (*1*), who suggested that for populations of *Orbulina universa* in the Indian Ocean, "larger tests do not necessarily indicate optimum regions." Figure 2, however, shows that for other species the temperature-salinity regions where maximum sizes occur are coincident with the temperature-salinity regions of maximum abundance of the species and phenotypes [the comparison is based on regions defined by the upper 10 to 20 percent of the species' abundances and test sizes (*9, 10*)].

Bradshaw (*11*), in an experimental analysis of benthic foraminifera, also suggested that "larger test sizes within the range of a species, do not represent optimum conditions" [see also (*12*)]. These observations suggest that the behavior of the planktonic foraminifera is distinctly different from that of the benthics.

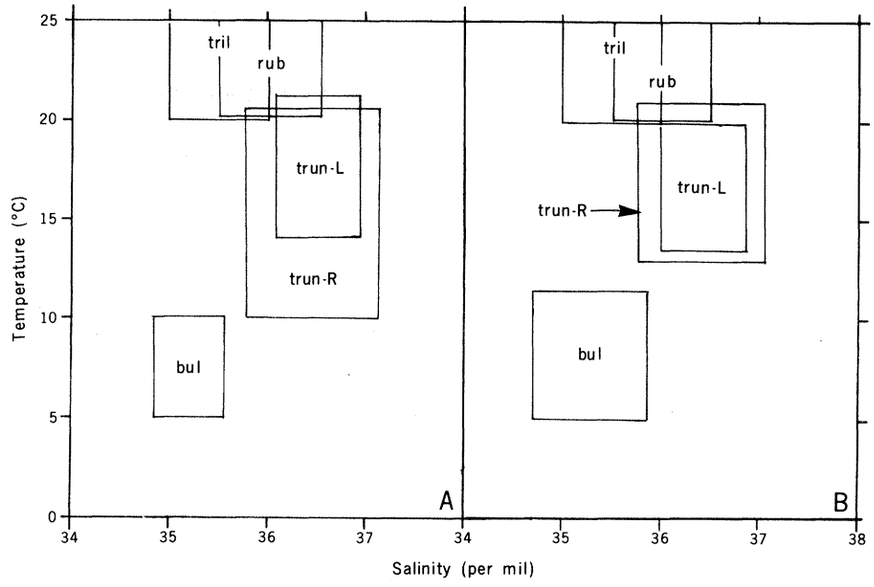

Fig. 2. Temperature-salinity regions of (A) maximum abundance and (B) maximum test size (*9, 10*). Abbreviation: rub, *G. ruber*; other abbreviations are as given in Fig. 1.

There are three major consequences of the model proposed here. These consequences may be of considerable value in the development of quantitative paleoclimatic models based on morphologic variations and in studies of the functional significance of shell design in planktonic foraminifera.

First, since there are size differences between phenotypes of the same species [for example, right- and left-coiling populations of *G. truncatulinoides*, and normalform, kummerform, pink, and white populations of *G. ruber* (*7*)], it may be desirable in determining morphologic gradients in a species population to separate the species into distinct phenotypes if the phenotypes dominate in waters of different temperatures and salinities. For example, is has been shown (*9, 13*) that phenotypes of a species, recognized on the basis of color and coiling direction, have statistical value in quantitative paleoecologic studies (considering the abundances of these phenotypes contributes to a reduction in variance in the estimation of ocean paleotemperatures).

Second, size variations in Pleistocene planktonic foraminifera may correlate directly, vary inversely, or show no correlation with paleotemperature changes, depending on the optimum temperatures of the species analyzed. For example, in the Caribbean Sea today, populations of *G. ruber* and *O. universa* are living near their optimum temperatures. Quantitative estimates of paleotemperature changes in the Caribbean Sea (*13*) suggest only small changes. Consequently, the glacial Caribbean may still have been optimum for these species, and therefore no significant size-temperature relationship would be apparent (*14*). However, in the Caribbean Sea, populations of *G. truncatulinoides* are living in temperatures and salinities below their optimum values. The glacial Caribbean would have been more favorable for this species, and therefore its abundance and test size would be expected to increase as the surface temperatures declined. There is good evidence that this is the case for populations of *G. truncatulinoides* in the Caribbean (*15*).

A direct relationship between size and abundance variations in populations of *Globorotalia menardii*, *Globoquadrina dutertrei*, and *Globigerina pachyderma* has been observed by Oba (*16*) in cores from the Indian Ocean. For these cores, tropical species decrease in test size while polar species increase in test size with decreasing temperature.

Finally, although it is apparent that there are size differences between phenotypes of a species, it is not known whether there are differences in other characteristics of shell growth. A detailed morphologic analysis of phenotypes living in optimum and nonoptimum environments could provide insight into the functional significance of shell forms. Such studies would indicate how a population responds to environmental stress. Comparisons of this type for several species and phenotypes from similar water masses may provide the basis for generating general ecologic models of foraminiferal shell growth.

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4. Bergmann's rule states that among living organisms, maximum size generally occurs in colder waters. This rule, in theory, applies to warm-blooded animals, but it is usually applicable to cold-blooded animals as well. While some species may show a size increase with decreasing temperature, it seems more reasonable to suggest that the maximum average size of a species should occur in its optimum regions, where such regions are defined in terms of several environmental factors. While in some areas temperature may be a dominant factor in controlling size, it is not necessarily the only variable of importance. See for example, H. B. Moore, *Marine Ecology* (Wiley, New York, 1966), pp. 24–30; D. V. Ager, *Principles of Paleoecology of the Marine Biosphere* (Prentice-Hall, Englewood Cliffs, N.J., 1973), pp. 119–125.
5. Data are reported only for samples where more than ten individuals could be measured, and where the samples are unbiased by solution effects. Morphologic gradients were determined for populations in size fractions 125 to 250 μm and > 250 μm. Similar environmental trends were observed for both size groups. Data are reported here for the size fraction > 250 μm. The curves drawn in Fig. 1A represent, for each temperature, the observed maximum average size for each species. The data from which these curves were drawn show a large variation in size within a population at any one temperature; this is probably due to factors, other than temperature, which affect a population's average size. The detailed geographic distribution of each species is given in (6).
6. A. D. Hecht, *J. Foraminiferal Res.*, in press.
7. *Globigerinoides ruber* pink, white, normalform, and kummerform populations have been differentiated. In normalform populations the final chamber of the last whorl is larger than previous chambers; in kummerform ones the final chamber is smaller than previous chambers. Pink populations are larger in test size than white ones, and kummerform populations are larger than normalform ones (6). The pattern size variations for *O. universa* in the Atlantic Ocean is similar to that reported by Bé *et al.* (1) for populations in the Indian Ocean.
8. Data given in Fig. 1B are replotted from data given in Kennett (2). Right-coiling populations of *G. pachyderma* are recognized as a separate species by R. Cifelli [*J. Foraminiferal Res.* **3**, 157 (1973)] and is called *Globigerina incompta*.
9. In the absence of experimental studies of test growth, optimum regions of a species' niche are usually defined by its relative abundances [J. S. Bradshaw, *Contrib. Cushman Found. Foraminiferal Res.* **10**, 25 (1959); A. W. H. Bé and D. S. Tolderlund, in *Micropaleontology of the Oceans*, B. M. Funnell and W. R. Riedel, Eds. (Cambridge Univ. Press, New York, 1970), p. 105]. Abundance data used in this study are based on a study of 191 core-top samples in the Atlantic Ocean as reported by Kipp (10). I plotted these data against winter surface temperatures and salinities, and from such curves defined the temperature-salinity ranges where abundances were in the upper 10 percent of the range. Temperature-salinity regions for maximum test sizes are from Fig. 1.
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14. C. Emiliani [*J. Geol.* **74**, 109 (1969)] indicates that size variations in Pleistocene populations of *G. ruber* are directly related to temperature in cores outside the tropics. Size variations in populations from Caribbean cores, however, are not related to changes in temperature.
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Enhancement of Algal Growth and Productivity by Grazing Zooplankton

Abstract. *Colonies of the common planktonic green alga,* Sphaerocystis schroeteri, *are only partially disrupted and assimilated by* Daphnia magna, *a natural predator. The* Daphnia *break up the outer protective gelatinous sheath that surrounds* Sphaerocystis *colonies, but most of the algal cells emerge from* Daphnia *guts intact and in viable condition. During gut passage, these viable cells take up nutrients, such as phosphorus, both from algal remains and from* Daphnia *metabolites. This nutrient supply stimulates algal carbon fixation and cell division. Enhanced algal growth, observed after gut passage, can compensate for the minor losses to the population caused by grazing. Nutrients regenerated by grazers may produce the summer bloom of gelatinous green algae during the seasonal succession of lake phytoplankton.*

Herbivorous zooplankton are traditionally considered to reduce the abundance of algae during grazing (1). However, recent studies show that primary productivity and the numbers of certain algal species increase in the presence of grazers (2–4). Nutrients, such as phosphorus, that are excreted by zooplankton (5) may stimulate the growth of algae not cropped during grazing. In this study, the uptake of excreted phosphorus and carbon by algae known to survive grazing (4) is documented and the contribution of this nutrient source to algal primary productivity and population growth is determined.

Cells of the colonial green alga, *Sphaerocystis schroeteri*, increase in number when the number of grazers is experimentally increased (3). Colonies consist of cells embedded in a complex polysaccharide sheath. They are ingested by *Daphnia magna*, *D. galeata mendotae*, and other natural predators, but more than 90 percent of the *S. schroeteri* cells are undamaged by gut passage through the grazers (4). Large colonies are broken into smaller clusters of cells with the loss of a few cells and sheath material. They are fed on by *D. magna* at a lower rate and are assimilated less efficiently than unsheathed unicellular green algae, such as *Chlamydomonas reinhardi* (Table 1) (6).

During gut passage, the intact cells of *S. schroeteri* take up nutrients from the remains of edible algae and from *Daphnia* metabolites. Light-dependent uptake and incorporation of phosphorus and carbon from algal remains were examined by allowing *D. magna* to fill their guts with a mixture of unlabeled *S. schroeteri* and *Ankistrodesmus falcatus* that was saturation-labeled with either $NaH^{14}CO_3$ or $K_2H^{33}PO_4$ (7). The spindle-shaped single cells of *A. falcatus* are easily assimilated by *Daphnia* and are easily distinguished from the palmelloid gelatinous colonies of *S. schroeteri* (Fig. 1a). After 1 hour of feeding in either the light or the dark, animals were anesthetized, fixed, dehydrated, embedded, sectioned, and examined for the distribution of radioactivity by using microautoradiography (8).

The heavy grain density over ingested *S. schroeteri* cells (Fig. 1, b and c) documents their uptake and incorporation of ^{33}P from *A. falcatus* remains in both the light and the dark. Carbon-14 is taken up and incorporated more in the light than in the dark. No incorporation of label by control *S. schroeteri* from *A. falcatus* cells in the feeding suspension was detected. The autoradiographs give a conservative indication of uptake since soluble label is removed during washing and dehydration and only label incorporated into fixed, insoluble cell components remains. Phosphorus uptake in both the light and the dark is expected since uptake and storage of phosphorus is independent of light (9). The predominance of light-dependent carbon uptake, however, suggests that it is primarily the result of autotrophic and not heterotrophic processes. The accumulated phosphorus and carbon may be taken up in both organic and inorganic forms.

Uptake of phosphorus from the metabolites of *Daphnia* was documented by feeding unlabeled *S. schroeteri* to *D. magna* that were saturation-labeled with ^{33}P and had empty guts (10). Feces containing intact *S. schroeteri* were collected and were examined for the distribution of radioactivity by using microautoradiography (8). Uptake and incorporation of ^{33}P from the metabolites of *Daphnia* were detected in the cells of *S. schroeteri* (Fig. 1d).

The effect of gut passage on algal