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THE FOREST NENETS MEDICINE

SPIRITS BEHIND A MUSEUM CURTAIN

DIATOMS: creators of glass castles

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HARMONY OF BEAUTY

Remaining together through forming colonies (lower organisms) or tissues (higher organisms) or becoming dispersed as the need arises is one of the fundamental principles of biological existence.

Having taken the evolutionary step of developing a rigid cell wall of two parts, an epitheca and a hypotheca surrounding a polarised cell, the diatom cells were, with very few exceptions, denied any choice in the manner in which they could remain together.

The only method available to them was to form chains if the cells remained attached to each other following cell division...

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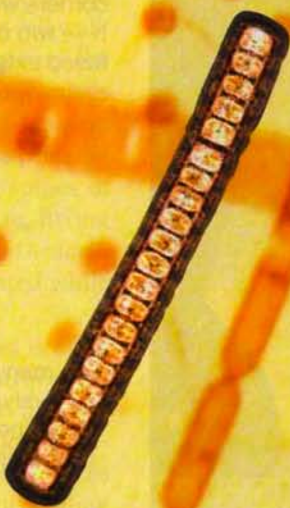
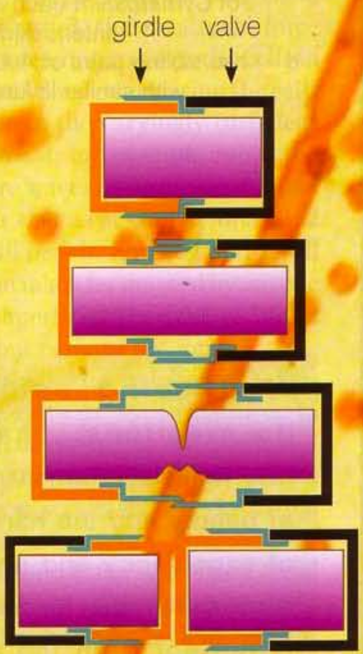
Everyone is familiar with the common, though misleading, perception that animals move and plants are rooted to the same place. The idea that, for those same plants dispersal is important in the form of pollen, seeds or in some cases vegetative parts of the parent, is also well known. So much for terrestrial systems, but such considerations are also relevant to aquatic environments. Only the vegetative (non-sexual) stages concern us here but, put simply, if a cell divides it can remain attached or it can become separated from its sibling and the two will be carried in different directions. If the cell has successfully grown and divided it usually means that conditions in the immediate environment are good and that it would thus be beneficial for both cells produced at the division not to be separated and to remain where they are. Obviously this is more the case when the parent cell is actually attached to a surface than if it is freely floating. On the other hand, separation of the cells would optimize dispersal, especially in a turbulent habitat, and this would be of clear benefit, for example in conditions of nutrient depletion. The opposite situation where dispersal is avoided is of further benefit to the population because it maximises the chance of encounter of gametes if a population enters a sexual phase.

It should be noted that among diatoms one can see that chain-forming species exist alongside unicellular ones. Chains are found in several kinds of habitat but chiefly epiphytic (attached to plants), epipsammic (to sand grains), epilithic (to stones or rock) and planktonic (free-floating in the water). In all situations the diatoms may be subject to considerable agitation due to the turbulence of the water and here we shall consider the forces that may be brought to bear on the diatom cell and particularly those cells that are bound together in a chain by means of linking spines.

AND EXPEDIENCY



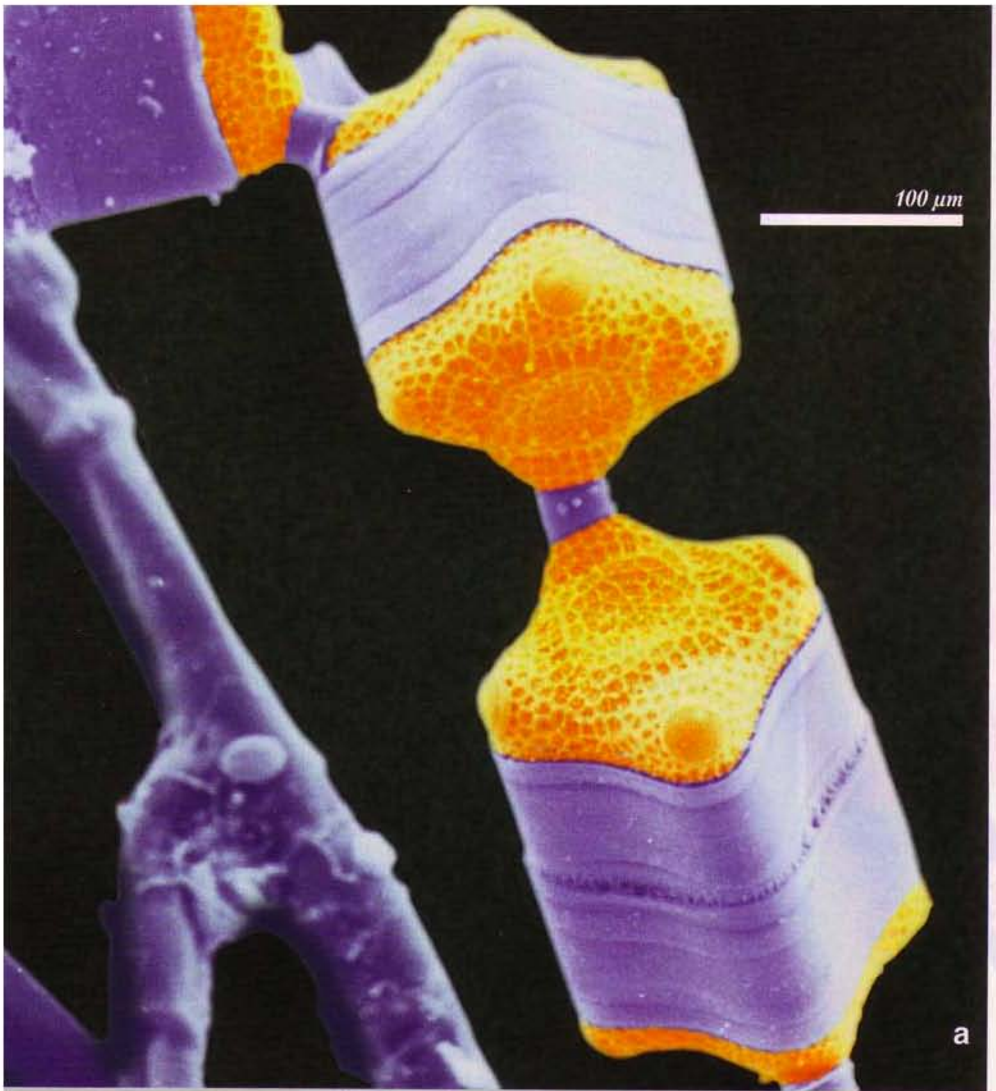


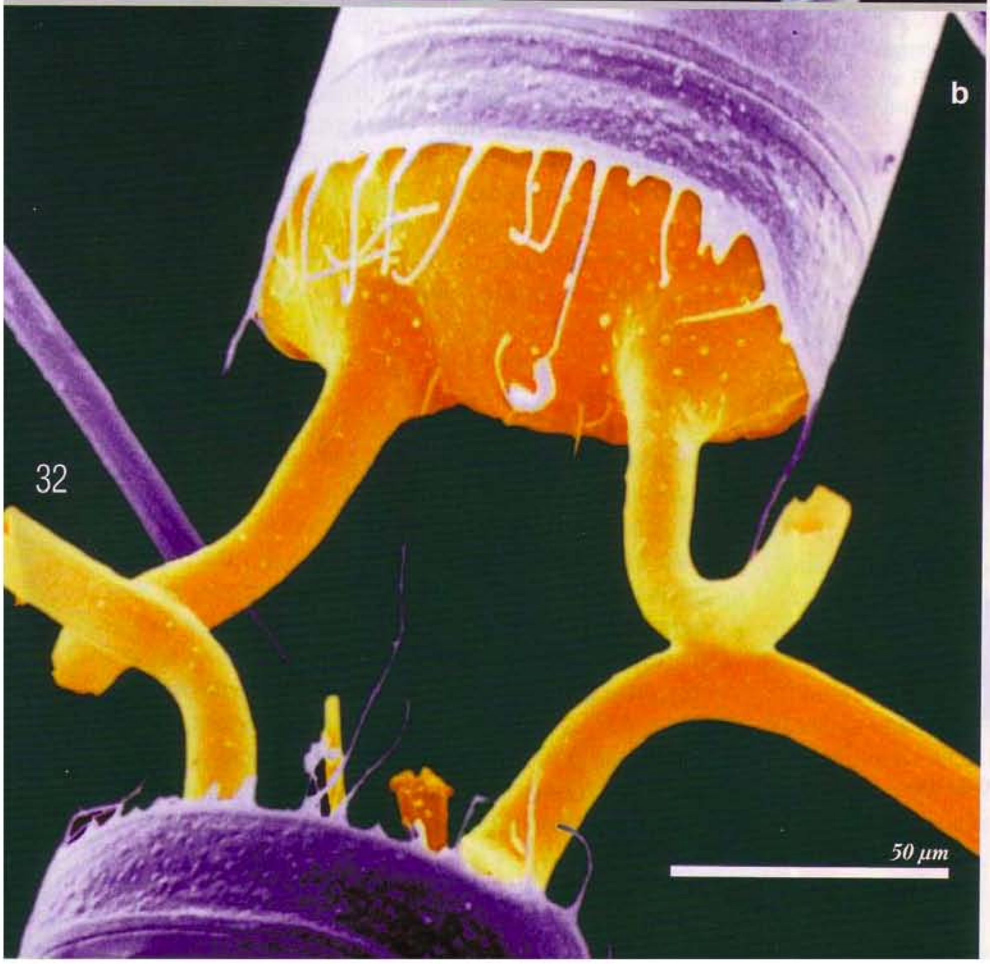
In some diatoms taxa both cells produced at the division may not to be separated

TRIBOLOGY (from Greek *tribos* — friction) is the branch of engineering that deals with the interaction of surfaces in relative motion (as in bearings or gears): their design, friction, adhesion, lubrication and wear. Tribology is the science and technology and practice. Recently, micro- and nanotribology have been gaining increasing interest. These fields deal with tribology at size scales of functional elements from 100 micrometers to some tens of nanometers. Frictional interactions in microscopically small components are becoming increasingly important for the development of new products in electronics, life sciences, chemistry, sensors and, by extension, for all modern technology.

The aim of biotribology is to gather information about friction, adhesion, lubrication and wear of biological systems and to apply this knowledge to technological innovation and to the development of environmentally sound products. This new interdisciplinary field of research combines methods and knowledge of physics, chemistry, mechanics and biology. There are many examples of tribology in biology. Surfaces in relative motion occur for example in joints, in the blinking of the eye and in a foetus moving in the mothers womb. Examples for systems with increased friction are bird feather interlocking devices and friction in fish spines

The field of biomicro- and -nanotribology was founded in response to strong needs of technology. Continuous miniaturization of technological devices such as hard disk drives and biosensors has increased the need for the fundamental understanding of tribological phenomena at the micro- and nanoscale. Biological systems excel at this scale and so their strategies may serve as templates for new engineering devices and the rigid parts of diatoms in relative motion and subject to various forces as we have seen above are therefore of particular interest for biomimetic microsystems engineering





There are different ways of cell-linking in chain forming diatoms:
a — cells of *Amphitetras* linked at corners with mucilage pads.
b — two cells of *Chaetoceros* with fused extensions of the cells walls

In many diatoms genera the sibling valves are linked by interlocking spines of varying complexity and size, fitting to each other like the key to the lock
c — two sibling pairs of valves of *Cymatoseira* each linked by interlocking spines
d — two sibling pairs of *Aulacoseira* with similar linking spines

"Producing each of its creations... nature intermingled the harmony of beauty and the harmony of expediency and shaped it into the unique form which is perfect from the point of view of an engineer" (M. Tupolev)

Like a key to a lock

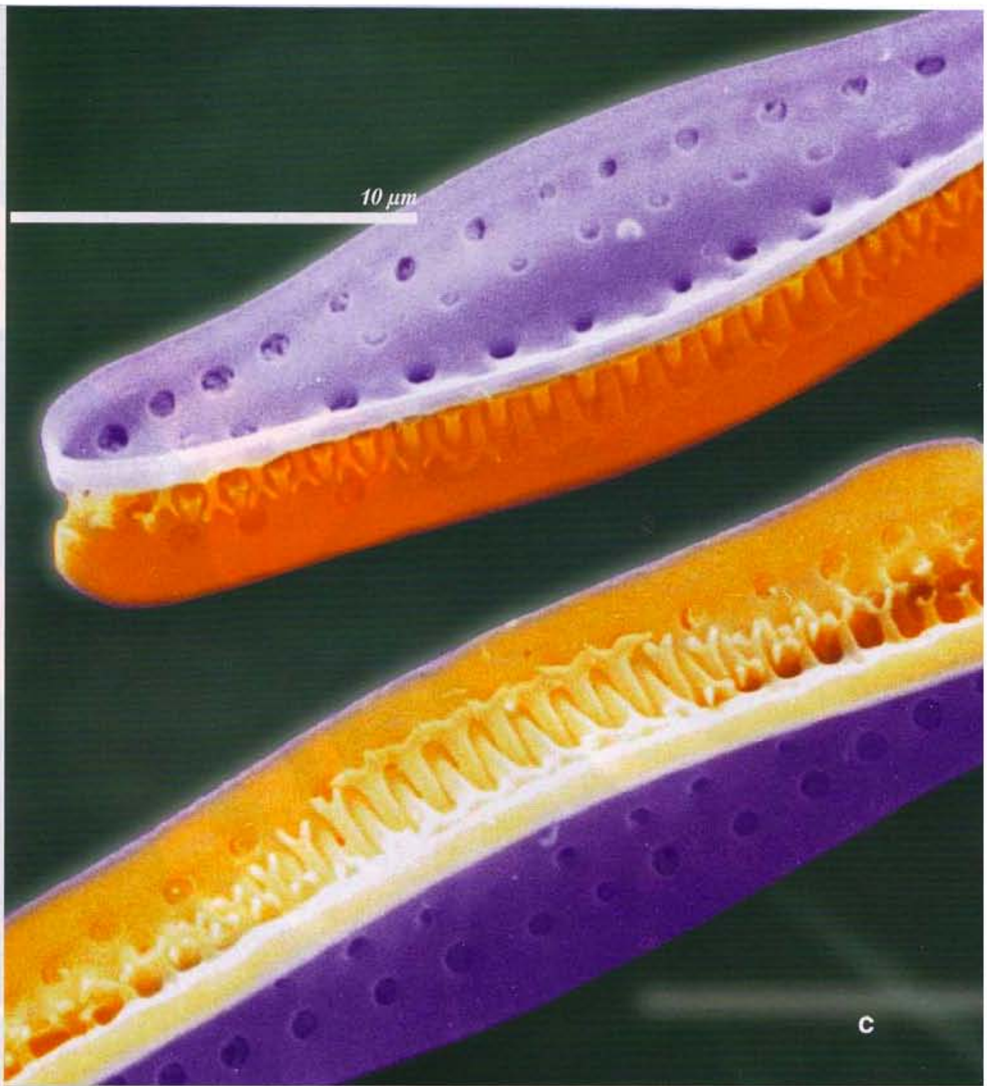
Three kinds of attachment may be found in diatoms.

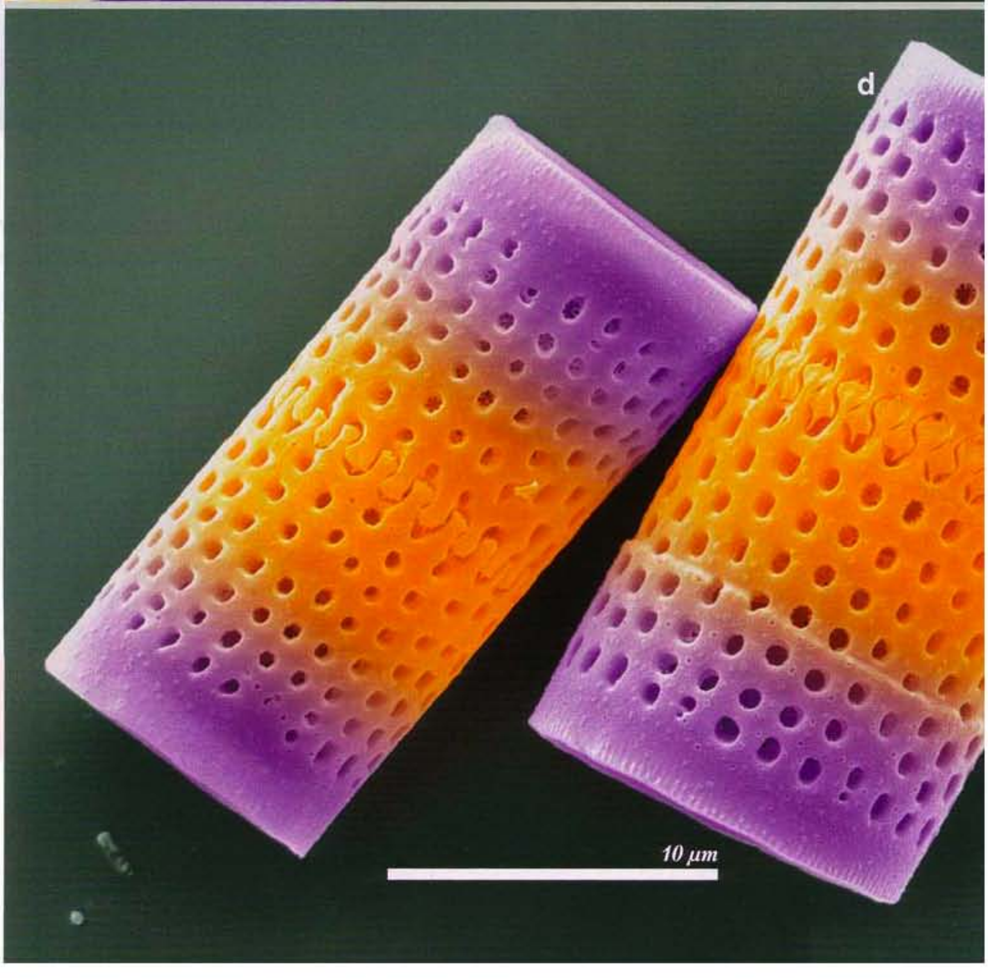
The cells may be attached by adhesive material that is passed to the outside through tubes in the cell wall. In a very small number of genera the siliceous structures of sibling valves may be fused. In many other genera the sibling valves are linked during formation by interlocking spines of varying complexity and size, fitting to each other like the key to the lock. Those structures are generated while sibling valves are forming.

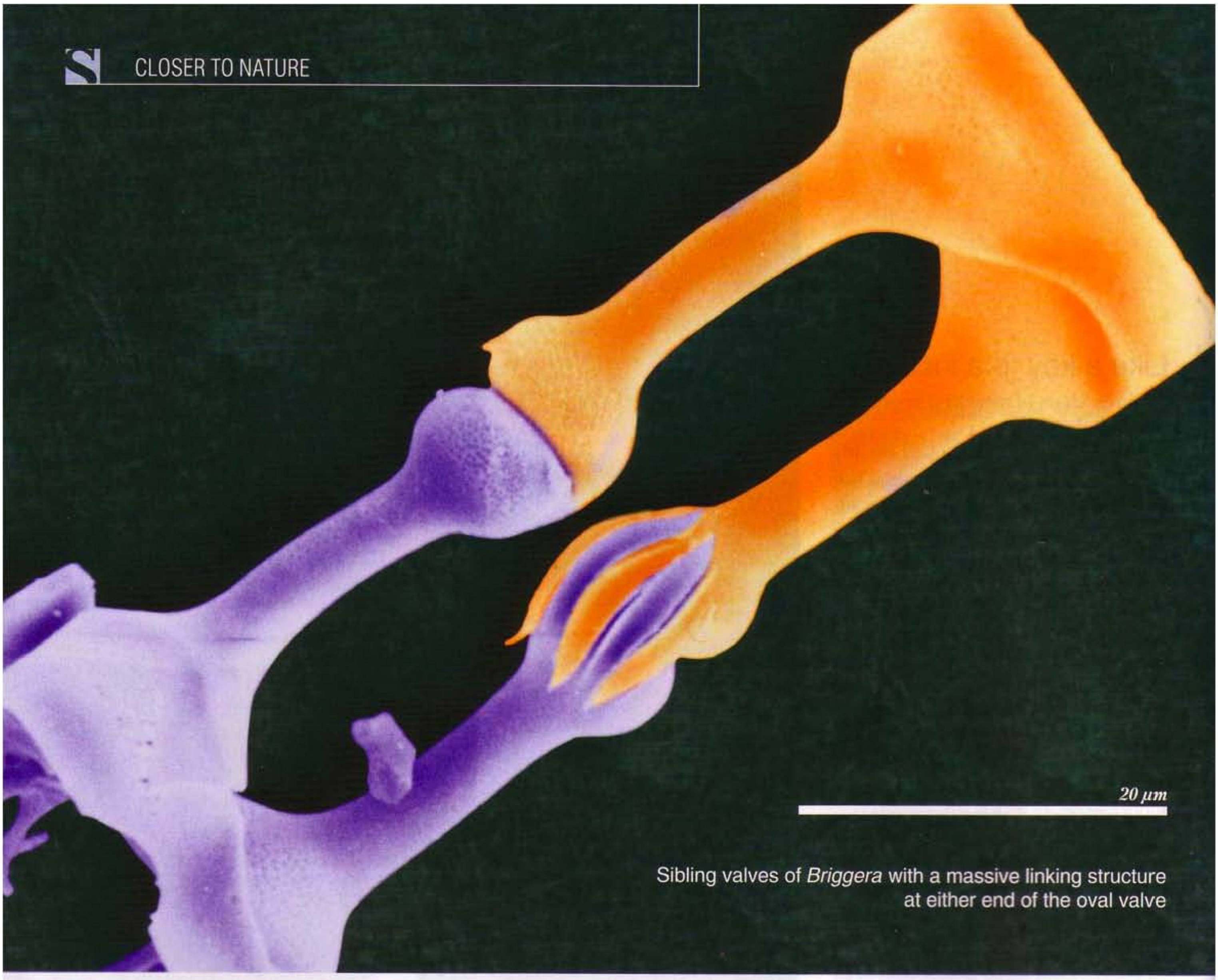
The design of these spines is often more than a mechanism constructed to keep cells from drifting apart and this prompted us to examine the forces acting on the cells in a chain. The forces are as follows. 1. the tension pulling cells apart; 2. the force pushing them together and 3, the rotational force or torque tending to twist the cells in the chain. When considering the cells of a chain in the varyingly turbulent environment, for example subjected to inshore waves on an exposed shore, it is clear that a cocktail of forces 1, 2 and 3 will be felt. Forces 1 and 2 will have been taken for granted by anyone giving superficial thought to life in a chain but perhaps not force 3.

We examined a number of chain-forming diatoms with this force in mind and have reached the conclusion that many diatoms have had to deal with it from very early times in diatom evolution.

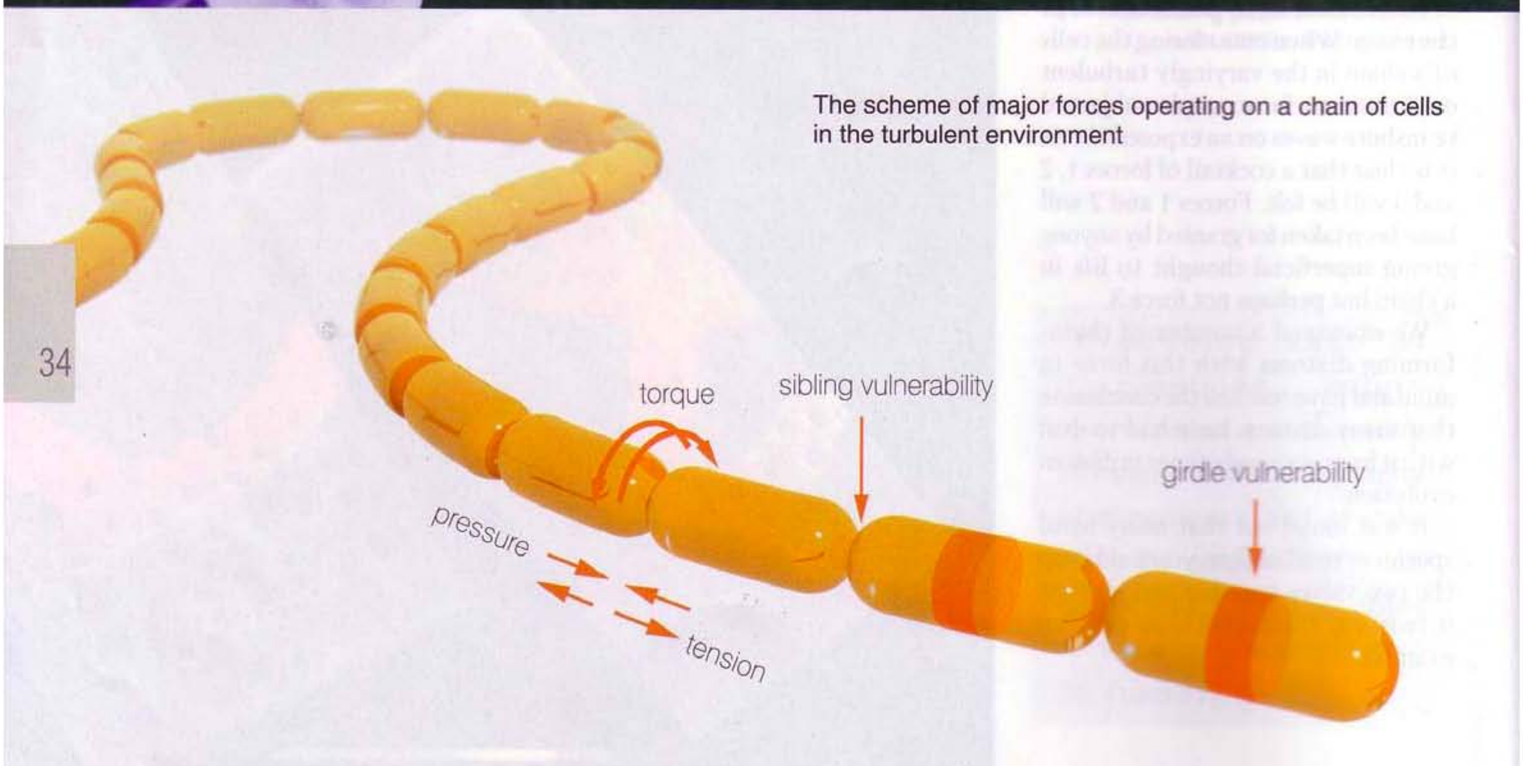
It was found out that many fossil species over 30 million years old keep the two valves together and prevent it twisting. *Ellerbeckia* is an extreme example.







Sibling valves of *Briggera* with a massive linking structure at either end of the oval valve



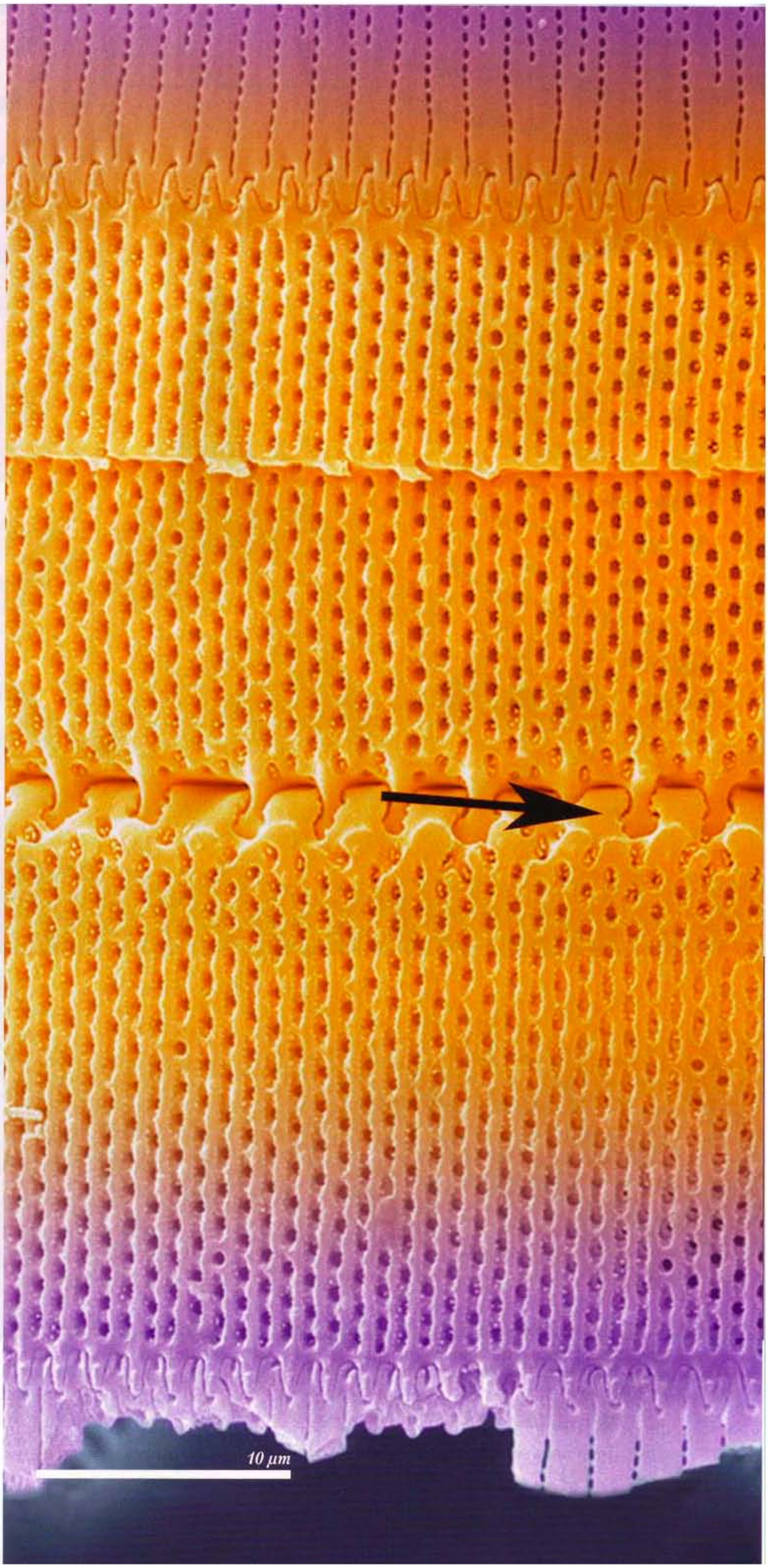
The scheme of major forces operating on a chain of cells in the turbulent environment

The engineering solutions of *Ellerbeckia*

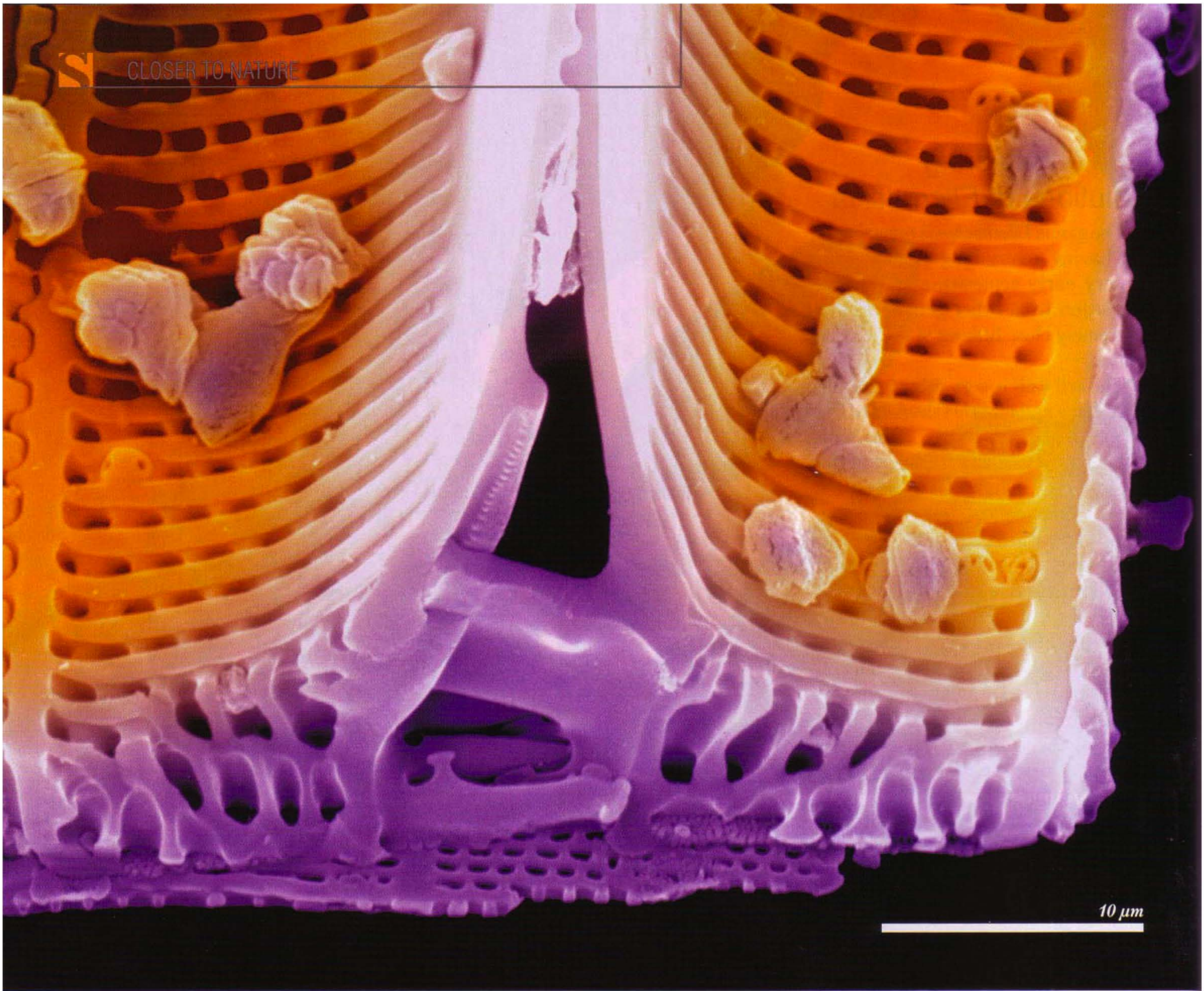
The genus *Ellerbeckia* is remarkable for having a very long fossil record, a very early separation in diatom evolution from other genera and an extremely close linking of the sibling valves.

The cell wall is very robust and the valve face and mantle (the side of the cell) are at right angles. If we look at the valve face of a fragment of the interlocked sibling valves we can see how intimately the features of one interlock with those of the other. In some species linking structures are found towards the middle of the valve face but visible here is a feature common throughout the genus ridges on one valve fitting into depressions on the other. If we examine linked cells from the side – the girdle view – we see that the spines are so closely interlocked that the two cells will not pull apart unless the spines are broken. Clearly with such linking structures the connection between two cells will neither be twisted nor moved together or apart very much but this leads us to another problem.

If the cell to cell connection is now safe from destruction the junction between valve and girdle bands will now be the weakest part of the chain and the most vulnerable to the various forces. Here *Ellerbeckia* shows us a unique character among diatoms. In all other genera yet recorded the interface of valve and first girdle band (valvocopula) is smooth. In most genera, especially in the "modern" motile unicellular diatoms, the valvocopula does not have a very close or precise relationship with the younger of the two valves, the hypovalve, but in *Ellerbeckia* all three components, hypovalve, valvocopula and epivalve, are locked very tightly and relate to each other as do two fists of a hand placed



Sibling valve junction of an *Ellerbeckia* species



Fragment of *Ellerbeckia* sibling valves showing relationship of both valves and the girdle band.
For a more complete understanding of the relationships see p. 14

knuckle to knuckle but with the girdle band between them.

The result of such a close connection at both of the potentially vulnerable sites might have one of two consequences. Either the chain is as solid a rod as if it were a string of fused cells (although this would increase the possibility of breaking the colony at high impact loads) or a certain amount of the energy transferred into the colony by the action of the forces (i.e. the work done on the chain) is dissipated through all of the small, but close, links between the components. It would seem that the whole system functions as one because we do not find chains with the occasional linking structure broken.

Why is it that in this genus we find a character that is found nowhere else among the multitude of diverse forms among the diatoms? Why do we not find a more secure valve/girdle/valve junction in ANY other diatoms? How is it that other diatoms, particularly chain forming species exposed to similar forces manage to avoid destruction? The answer is probably in the evolution history of this old genus formed in shallow turbulent seas of the past. The fact that other, quite different genera thrive just as well alongside *Paralia* and *Ellerbeckia* adds to the mystery but is at least testament to the great diversity of the diatoms and to their thrival strategies. This diversity may prove to be a rich vein of discovery for the biotechnology of the future.

Photos by the courtesy of R. Crawford