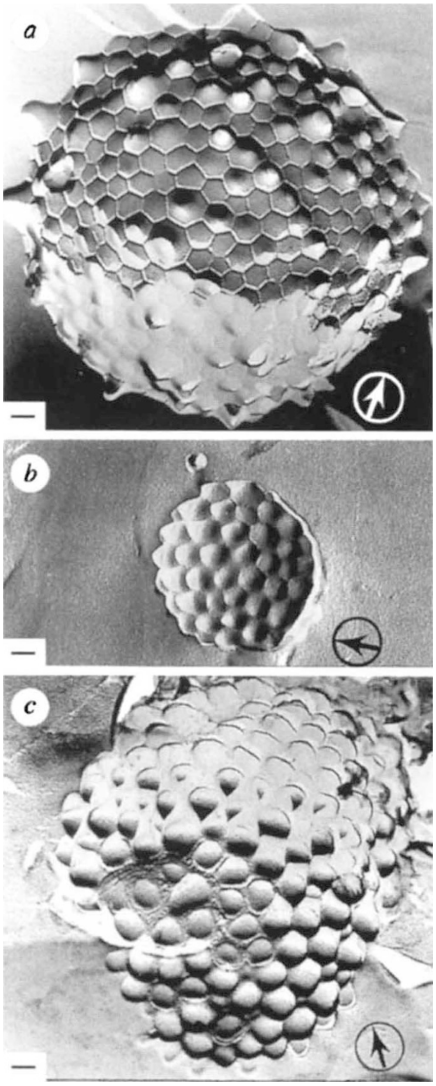
Geodesic surfactant structures

SIR — Structures formed by the self-association of amphiphiles (liquid crystals, vesicles and micelles) excite interest because of their potential uses as vectors for drug and gene delivery (see, for example, ref. 1), and as matrices from which new structured materials can be made (for example, ref. 2). We have used spherical nonionic surfactant vesicles (niosomes)[3], which are synthetic analogues of liposomes, as vehicles for drug delivery[4,5], and have identified in some of them mixtures of nonionic surfactants with cholesterol and either cholesteryl(24)polyoxyethylene ether or dicetyl phosphate. These structures include large (10–50 μm) disk-shaped vesicles, or discomes[6]. In studies on a range of niosome dispersions, freeze-fracture electron micrographs reveal related novel vesicle aggregates, which look like geodesic spheres or raspberries, respectively, and which we term 'multiniosomes' (see figure).



Freeze-fracture electron micrographs (bars represent 100 nm; shadow direction marked by circled arrow). *a*, A geodesic multiniosome. *b*, An intermediate state; the spherical shape is less clear, with no radial foreshortening (except perhaps at the left edge). Facets are convex and their boundaries are mostly unclear, except for one vertical etched line near the middle. *c*, A raspberry structure found in dispersions of sorbitan mono-oleate (Span 80). In the geodesic multiniosome, the vesicles are tightly packed and in the raspberry structure they are more loosely arranged, held together by an envelope of one or several membranes (*c*). In the intermediate state (*b*) the pressure leads to a higher degree of order in the raspberry structure (left side) and shows some features of the geodesic multiniosome form (right side).

Niosomes were prepared from sorbitan mono-oleate (Span 80), cholesterol and dicetyl phosphate (in the molar ratio 19:19:2) by dissolving the lipids in chloroform, removing the organic solvent and drying the lipid film with oxygen-free nitrogen. The dried lipid film was hydrated with distilled water and the resultant multilamellar vesicles left to cool to room temperature. The system was quenched rapidly using the sandwich technique, and metal-shadowed at –120 °C in a Balzers BAF 400D freeze-fracture system.

Examination of the cleaned replicas in a Jeol 100B electron microscope[7] revealed previously unreported structures (see figure). The most striking of these (*a* in the figure) is clearly spherical, and its surface is covered with facets, mostly flat, whose straight boundaries are deeply etched. These resemble the framework of a geodesic dome, suggesting that they are formed from a monolayer of close-packed niosomes on the surface of a large (2 μm) spherical vesicle, similar to the 'wafer structure' seen in the membranes of *Streptomyces hygroscopicus*[8], and thought to result from the hexagonal or cubic organization of membrane phospholipids between the lamellae of artificial lipid membranes.

The 'raspberry' structure (*c* in the figure) is apparently not spherical, perhaps a result of internal packing of the small spherical vesicles, either through hexagonal close-packing or in a face-centred cubic lattice. Near and parallel to the right-hand edge is a row of three squares, each with full-size spheres at the corners and smaller spheres in the centres. The smaller spheres could be the tips of vesicles from the layer beneath, positioned according to a face-centred cubic lattice. The hexagonal packing of full-size spheres over most of the bottom could represent the (111) face of a face-centred cubic lattice.

The best explanation for the raspberry structures thus seems to be that they are an aggregate of small spheres (niosomes) packed in a somewhat disordered face-centred cubic lattice. It would be simplest if the three structures in the figure were fundamentally similar, that is, that they were all niosomes close-packed to give an aggregate like a solid foam (with the gas replaced by water). The flocculation of small vesicles, either together or with a much larger vesicle, is perhaps caused by something akin to a phase separation at low temperature. Nonionic vesicles containing dicetyl phosphate have a surface negative charge, and the sorbitan head groups will have a low degree of hydration which would otherwise provide some degree of enthalpic repulsion on close approach of the vesicles at room temperature. A better understanding of such vesicle–vesicle interactions may shed light on cell–cell interactions.

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HOT and the North Pacific gyre

SIR — Karl *et al.*[1] report changes in conditions at the Hawaiian Ocean Time Series (HOT) station ALOHA (22°45′ N; 158° W) and that these indicate a significant change in the structure and productivity of the pelagic ecosystem of the subtropical North Pacific. The changes were associated with and perhaps due to an intensified near-surface stratification and a shallower mixed layer. This station is, however, unlikely to be "representative of the oligotrophic North Pacific Ocean habitat", as stated by Karl *et al.*

Station ALOHA was established to "assess and interpret annual- to decadal-scale ecosystem variability in the North Pacific subtropical gyre"[1]. Measurements there "are designed to obtain oceanographic data on the physics, chemistry and biology of this representative North Pacif-