polarization microscopy. As pointed out by Prusiner and colleagues, amyloid deposits have been seen in a number of degenerative disorders of the central nervous system. A direct link between the putative rods associated with scrapie and amyloid would provide a major clue to the aetiology of a number of degenerative diseases. Unfortunately, the association between prions and amyloid is not yet certain as normal cells contain rod-like structures, and 'prions' have not yet been completely purified[5].

Clearly, the means by which viruses can injure their hosts are diverse. These include injury due to subtle effects on cell metabolism without overt pathological change, the production of autoantibodies to tissue components or products, and the deposition of material related to normal cell products. What remains to be determined is which of these strategies of virus-induced injury are important in causing human disease. ☐

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Natural materials

Chalky submarines

from Paul D. Calvert

MOST of us, if asked to design a submarine, would not think of chalk as a very suitable constructional material. But a recent paper by Birchall and Thomas (*J. Materials Sci.* **18**, 2081; 1983) on the structure of cuttlefish bone illustrates how good design can procure impressive performances from the most unpromising starting materials.

The cuttlefish (*Sepia officinalis*, a relative of the squid) maintains neutral buoyancy at varying depths in the sea by pumping water into or out of the cuttlebone which is divided into small closed compartments. When empty of fluid these cells are at a pressure of about 0.8 atmospheres. Hence they must withstand a high external hydrostatic pressure corresponding to the depth of the fish (1atm per 10 m).

The cuttlebone structure comprises parallel sheets of calcium carbonate (aragonite) about 10 µm thick separated by 200–600 µm. The sheets are held apart by pillars after the manner of a multistorey car park except that each layer is sealed from those above and below. The whole assembly is supported on a 1.5 mm dense bony dorsal shield.

The obvious design for a pressure-resistant vessel is a thick-walled hollow sphere — just as seen in a bathysphere. A simple calculation for a given compressive strength of the material would give this sphere a density of about 75 per cent of either a layered pillared structure or a cylinder. Birchall and Thomas measure the same crushing strength perpendicular or parallel to the layers as the structure has to resist uniform hydrostatic forces. Apparently, the cuttlefish trades the improved depth resistance that would come from a spherical pressure vessel for an elongated cuttlebone which can also act as an internal skeleton. The pillared layer structure bears a strong resemblance to the skin-and-honeycomb panels used to obtain maximum rigidity with minimum weight in aircraft and provides a light and rigid skeleton for the cuttlefish.

A problem with using such an intrinsically brittle material as chalk is that it can be quite strong in compression but relatively small tensile loads can produce failure. Much of the design of the medieval cathedrals can be seen as an exercise in minimising or eliminating tensile loads, but the cathedrals did not have to swim around and fight. One way of circumventing the problem is to ensure that local failure does not lead to catastrophic collapse. Crushing tests show that the cuttlebone does fail by a progressive collapse of the layers rather than imploding as would a hollow structure.

The cuttlefish would also like to get as much tensile strength from the material as possible without sacrificing compressive strength or rigidity. This is also very much a concern in the production of synthetic ceramics both in the context of 'high performance' ceramics, which are the subject of a recent Japanese initiative (*Nature* **305**, 373; 1983), and in the high-strength cements developed by Birchall and his co-workers (*Nature* **289**, 388; 1983). For maximum strength one would like a fine grain size; very small pores, if any; and strong bonds between the grains. The key to the high strength of biological ceramics is their four per cent organic component — a protein–chitin complex which forms a layer covering the carbonate surface. The organic component acts as a nucleating surface for the aragonite crystals and may play a more important part in preventing the crystals from growing too large and/or in improving the bonding between the crystals. S.A. Wainwright and co-authors discussed these ideas well in *Mechanical Design in Organisms* (1976).

The operating parameters for a cuttlefish seem quite respectable when compared with submarines. The cuttlebone crushes at pressures corresponding to a depth of about 230 m and cuttlefish have been recorded at depths of 200 m. The osmotic pump which controls the gas–fluid exchange in the bone would not work beyond about 240 m. By comparison large submarines are reputed to be limited to operating depths of 300 m, which is only about twice their own length, despite being constructed of far stronger materials. It seems almost sacriligeous that such a sophisticated structure as cuttlebone should frequently end up as a budgerigar's beak cleaner! ☐

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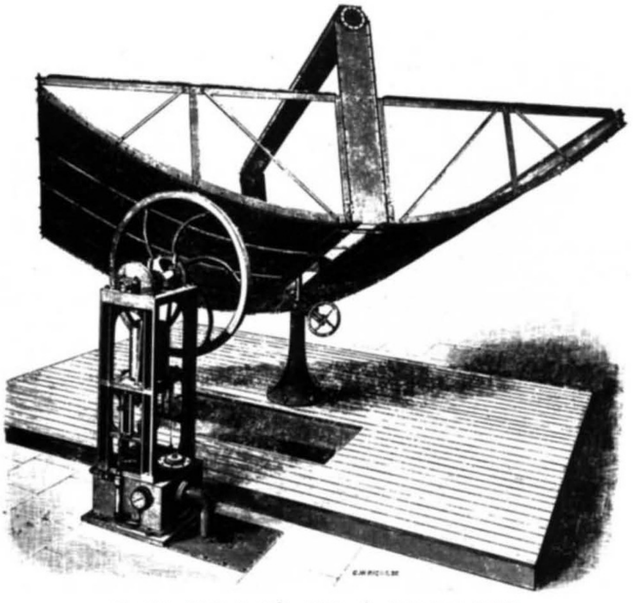
100 years ago

THE SUN MOTOR

THE illustration represents a perspective view of a sun motor put in operation last summer. The leading feature of the sun motor is that of concentrating the sun's radiant heat by means of a rectangular trough having a curved bottom lined on the inside with polished plates so arranged that they reflect the sun's rays towards a cylindrical heater placed longitudinally above the trough. This heater contains the acting medium, steam or air, employed to transfer the solar energy to the motor; the transfer being effected by means of cylinders provided with pistons and valves resembling those of motive engines of the ordinary type.



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