reluctant to think of the cells as electrically inactive. If nerve cells can make contacts that look like synapses, at which no electrical interaction occurs, then the morphologist is bound to question the significance of the features that are classically considered diagnostic of a synapse.

The transient cells may also serve as tropic markers or 'guideposts' providing a telencephalic equivalent to the guidepost cells defined for developing pathways in other nervous systems[4]. On either hypothesis, however, the function of the axons remains obscure. The long intercerebral pathway is particularly difficult to understand. If it provides a precursor of callosal pathways, why are such precursors needed?

A further possibility is that the transient cortical cells represent the exploitation during mammalian development of cells surviving in the adult of pre-mammalian forms[5]. This would account for the origin, but not for the function, of the cells.

The sequence of developmental events producing the circuitry of the adult brain is extraordinarily difficult to understand. Even where the complexities of the adult are understood (there are few such regions: the cerebral cortex is certainly not one) there are no clear ideas about the ways in which specific patterns of connections are formed. Guidepost cells, substrate pathways[6] or temporary neural projections that are obliterated or pruned and corrected[7], provide a conceptual crutch for understanding how complex patterns of connectivity could be formed. But temporary measures for carrying instructions that eventually make a brain are like messengers arriving at a general's headquarters — it is useful to see them arriving, and perhaps even to identify them, the course of their journey and their effect on subsequent events, but the outcome of the battle will be most clearly understood if the nature of the message and the instructions given to the messenger (not necessarily distinguishable) are understood. On these subjects developmental neurobiologists must, as yet, remain silent. □

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100 years ago

BUBBLES in ice are familiar; but their arrangement and progressive development in the process of freezing-over present some points which I do not think have been generally observed. The following facts must be noticed: (1) Ice over deep water invariably contains fewer bubbles of included air and gas than ice formed over shallow water. (2) The upper portion of a coating of ice invariably contains less included air than its lower portion. (3) There is more included air ice formed over water in a small vessel than ice formed over a large body. (4) There is more included air in an entirely frozen mass of ice than in surface ice from a partly frozen vessel. (5) In freezing separately the water from which the first frozen coat of ice had been removed, the ice contained a much larger proportion of included air than either the surface ice or the ice obtained from entirely freezing a body of water.

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Topology

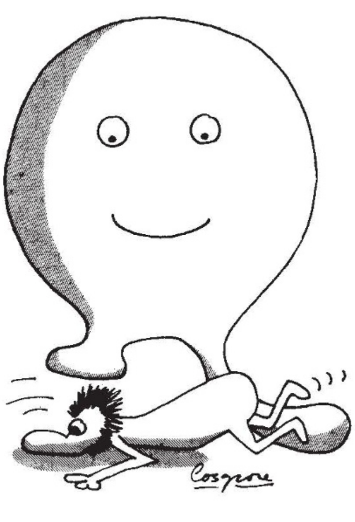
The three-sphere strikes back

Ian Stewart

ALMOST a year ago I reported in a News and Views article (*Nature* **320**, 217–218; 1986) the announcement, by Eduardo Rêgo and Colin Rourke, of a proof of the Poincaré conjecture — one of the major unsolved problems of topology. At first, the mathematical community regarded the claim with scepticism. There were good reasons for this. Proofs have been announced before, and retracted soon after, by many distinguished mathematicians. Some thought that Rêgo and Rourke's methods were not novel enough. Their proof was also long and complicated, difficult to grasp in its entirety and rather sketchy in places. But, for the time being, the sceptics are right.

During the first year, the proof was subjected to thorough scrutiny by the mathematical community. Against most predictions, it held up well until early November 1986. Then Rourke gave a series of seminars to an audience of experts at the University of California at Berkeley, whose objective was to settle the matter once and for all. During a routine discussion, Rourke realized there was a mistake, and pointed it out to the audience. It is in the nature of mathematics that a defective proof is no proof at all, so the original announcement was wrong. But the story may not be over yet.

The conjecture is about manifolds, which are among the most important objects in topology. Manifolds are spaces which 'in the small' resemble ordinary euclidean space, but which, 'in the large', can bend round upon themselves, twist up in complicated ways, have holes and so



on. In topology, two manifolds are considered to be the same if one can be obtained from the other by a continuous deformation. The surface of a sphere, and that of a torus (or doughnut), are two-dimensional manifolds, but they are topologically distinct because the torus has a hole whereas the sphere does not.

One way to detect the hole in the torus is to thread a loop through it. This loop cannot be shrunk continuously down to a single point while remaining on the surface of the torus. In contrast, on the sphere, every loop can be so shrunk. During the nineteenth century, mathematicians were able to find all possible topological types of two-dimensional manifolds. One consequence is that the only two-dimensional manifold on which all loops can be shrunk to a point is a sphere.

Poincaré was interested in the next step: three-dimensional manifolds, which are much more complicated and at one of the great open frontiers of topology. Even the simplest questions remain unanswered, and the most basic is Poincaré's.

The natural three-dimensional generalization of the two-dimensional sphere is what Poincaré called a hypersphere, and is now called a three-sphere. In the hypersphere, as in the ordinary sphere, every loop can be shrunk to a point. Poincaré asked whether this property completely characterizes the hypersphere. If every loop in a given three-dimensional manifold can be shrunk to a point, must that manifold be topologically a hypersphere? Poincaré asked the question in 1904, and nobody knew how to answer it, although it was widely assumed that the answer must be yes. The problem was still open when Rêgo and Rourke announced their proof.

Their method is technically complicated, but based on familiar ideas (some, indeed, going back to the time of Poincaré). They start with a description of a three-dimensional manifold in terms of a system of links. They assume that every